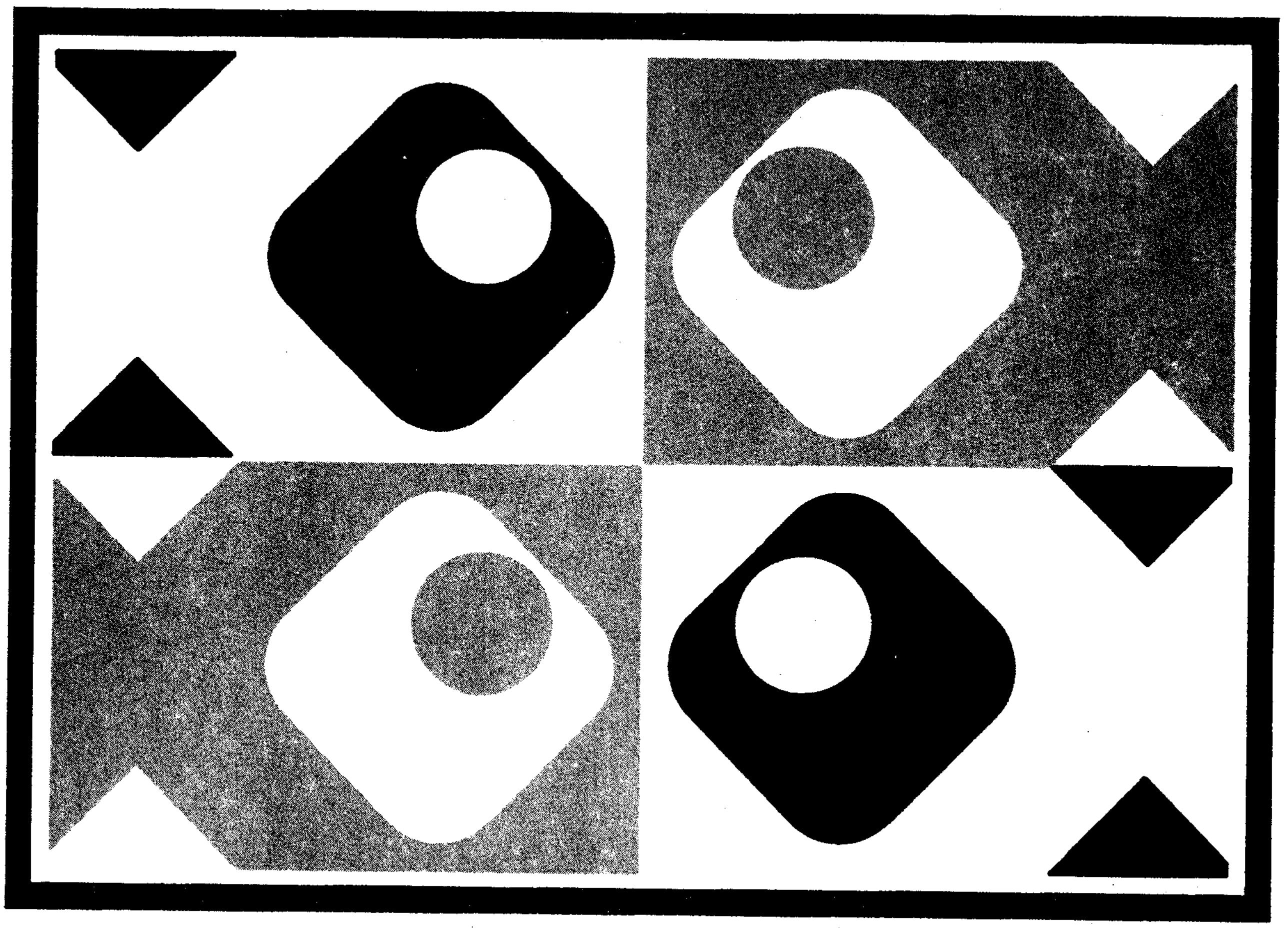
Status of Pacific Oceanic Living Marine Resources of Interest to the USA for 1991



NOAA Technical Memorandum NMFS

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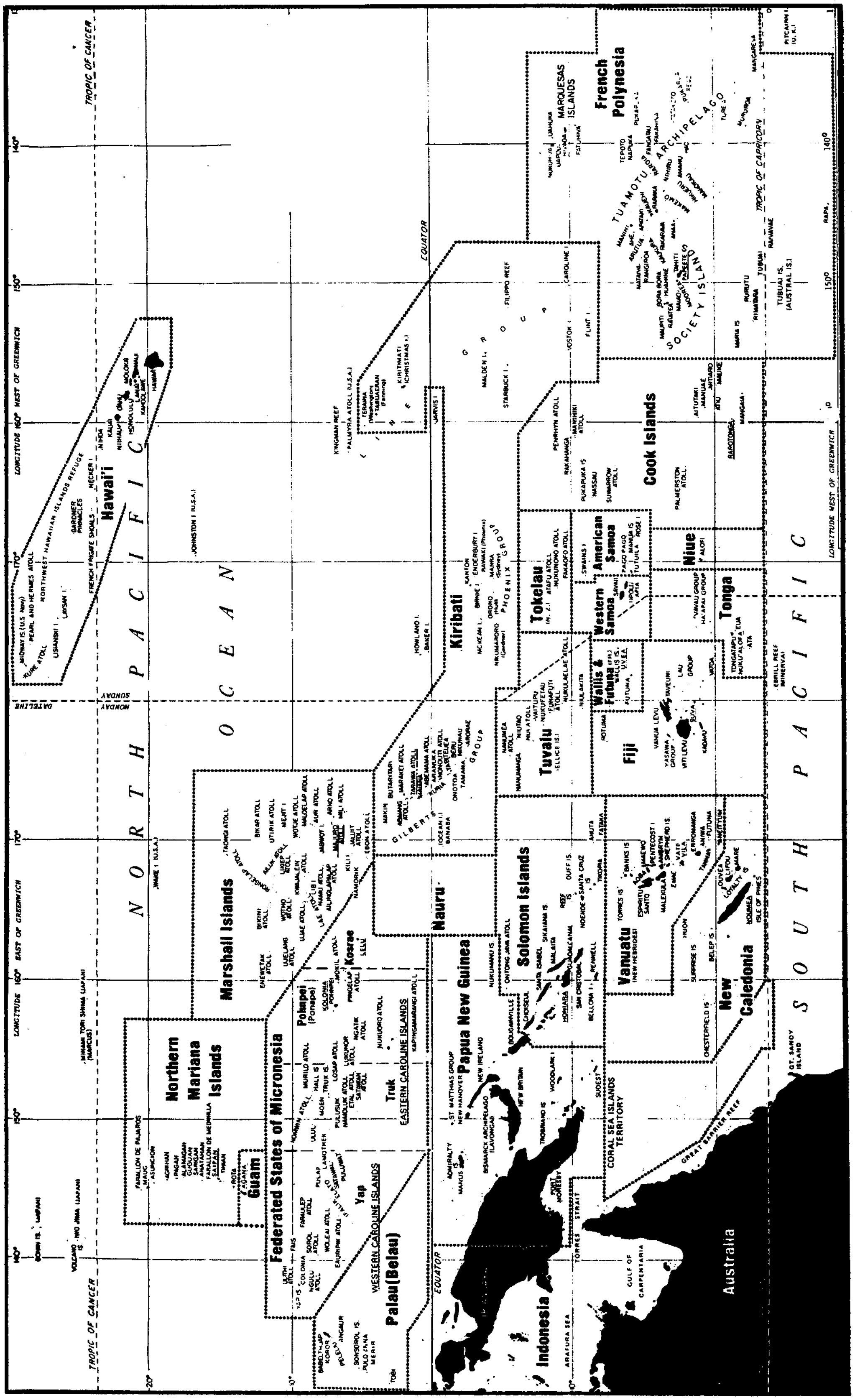
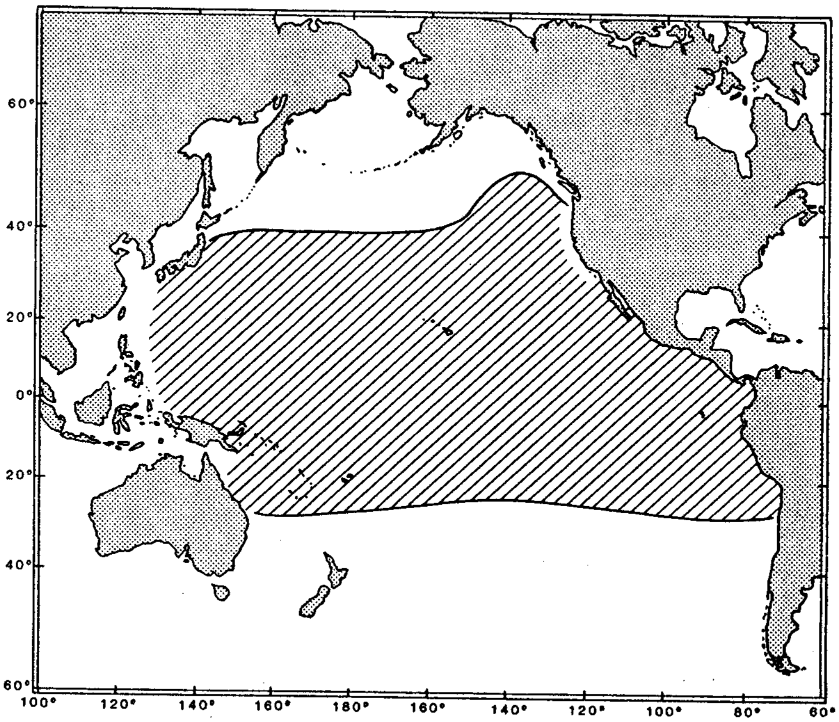


A detailed view of the Pacific islands area covered in this Technical Memorandum (see next page for a general map of the total area).

INTRODUCTION

The area of the Pacific that encompasses the oceanic fisheries and protected species covered here is a vast one. It stretches from the domain of eastern tropical Pacific tunas off Mexico and Central and South America, to the northward edge of the albacore tuna's range at around 45°N latitude, and throughout the central and western Pacific Ocean (see map to right).

Primary emphasis is on the central and western Pacific region, which includes the Hawaiian Islands as well as 14 independent of self-governing countries and eight territories, including the U.S. territories of American Samoa, Guam, and the Northern Marianas (see map on facing page). These island countries and territories are marked by high economic dependence since they have narrow economic bases and their agricultural resources and land-based economies are limited. In general, the area can be characterized as comprising tropical and subtropical, high seas waters with relatively few species and moderate productivity, and tropical and subtropical island-related waters with a large diversity of species but relatively low sustainable yields due to limited nutrients. The region has a complement of marine mammals and turtles that have protected species status. Habitat protection is an aspect of the work in this area--the fragile reef areas, beaches, and water quality of Hawaii and other island areas are vital for fish production and protected species. All of these habitats come under threat of pollution or development.



The oceanic fisheries and protected species area covered in this Technical Memorandum. Other Pacific coast fisheries are covered in the companion document " Status of Living Marine Resources off the Pacific Coast of the United States for 1991."

Information presented here has been prepared for administrators, managers, the fishing industry and the interested public by the scientific staff of the National Marine Fisheries Service, Southwest Region, Southwest Fisheries Science Center (SWFSC), with headquarters in La Jolla, California. It summarizes the general status of selected fishery resources--large pelagic fishes, lobsters, corals, bottomfish, marine mammals, and sea turtles of interest to the U.S. in the western and central Pacific in 1991, and includes several species which range into the eastern central and eastern tropical Pacific. This report is in two sections: Summaries and Species Synopses. The Summaries section includes a brief history of Pacific Oceanic fisheries, discussion of fishery management for each group where appropriate, overview of assessment approaches, fishery landing trends, commercial fishery economic trends, and trends for protected species. The Species Synopses section includes information about the status of 18 individual species or species groups.

The Species Synopses section has been grouped under four headings: large pelagics, insular species, marine mammals, and sea turtles. For the convenience of users, an information digest of the Species Synopses, definitions of technical terms, and a common and scientific name index have been included as Appendices to this report.

HISTORY OF PACIFIC OCEANIC FISHERIES

In the years that immediately followed the end of World War II, there have been many significant changes, not only in ocean law, but also in ocean sciences and in the economics of marine resources. The western and central Pacific is a classic example of an area where a vastly expanded scientific knowledge of the oceans, including an enhanced understanding of living marine resources, has intersected with strong market forces stimulated by a consistently rising world demand for animal protein and most recently, an aggressive expansion of fishing by ships from around the world. The result brought enormous pressures on ocean fishery resources leading to the United Nations-sanctioned movement for enclosure--exclusive economic zone of 200 miles' distance offshore. In the view of experts, this movement portends the most profound and sweeping changes influencing the exploitation and conservation of marine resources.

The Federal Government was first in the field to investigate the potential marine resources of the area. In 1947, the U.S. Congress passed the Farrington Bill, which directed the then Secretary of the Interior to conduct fishing explorations and related oceanographic, biological, technological, statistical, and economic studies to insure the maximum development and use of the high-seas fishery resources of the territories and island possessions of the United States in the tropical and subtropical Pacific Ocean.

The Pacific Oceanic Fishery Investigation, now the National Marine Fisheries Service, Southwest Fisheries Science Center, Honolulu Laboratory, was established under this authority in 1948. With the Division of Fish and Game of the Hawaii Department of Land and Natural Resources and the University of Hawaii which has conducted basic research on fishes for many years, a very large body of new information and data on Pacific oceanography, including physical, chemical and biological aspects of the marine environment in the Pacific Basin system, has been generated. The consensus is that during the years immediately following the end of World War II, they have accomplished nothing less than a quantum leap in knowledge of the Pacific Ocean and its resources. This has led directly to an unprecedented expansion of commercial fisheries in the western and central Pacific, of which more will be discussed later in this report.

NMFS Honolulu Laboratory has made many contributions to this data base. It has been credited for discovery of yellowfin tuna stocks in the equatorial Pacific and of skipjack tuna in the Marquesas Islands, for its elucidation of the complex pattern of albacore migrations in the North Pacific, for pioneering research on the physiology and behavior of tunas and oceanographic studies of the central Pacific. At present, Honolulu Laboratory scientists assess the biological condition of shrimp, lobster, snappers, groupers, and seamount fish populations, and monitor the major commercial fisheries for tuna, bottomfish, mahimahi, billfish, and lobster. This information is critical to the Western Pacific Regional Fishery Management Council and international fisheries commissions in the management of these resources. Another important aspect of the on-going research program is the cooperation with researchers from other nations on marine resources of mutual concern, and the collection and analysis of data on the growing fisheries of the Pacific high seas.

Unlike temperate regions where relatively few species are the basis of large fisheries, the shallow coastal waters around islands and reefs abound with numerous species, but only a few are of economic importance. Varied though the fishery resources are, five species of tuna account for most of the catch--skipjack tuna, albacore, bigeye tuna, little tuna and yellowfin tuna--fishes which have historically been caught throughout the area. The first European visitors, late in the 18th century, described the canoe fishery for skipjack. It is interesting to note that Oahu's most famous landmark, Diamond Head, took its Hawaiian name--Leahi--from its resemblance to the dorsal fin of tuna. The skipjack fishery had a prominent place in Hawaiian mythology. Kapus (tribal taboos) protected the fish at certain times of the year. The origins of the commercial catch are lost in history, but it is known that some of the first Japanese to reach the islands--shipwrecked fishermen rescued early in the 19th century by American whalers--earned their livelihood by fishing and selling skipjack.

The people of the central and western Pacific have always depended on the marine environment for food. In the Pacific, small-scale fishing is more important to residents of islands with limited land resources than it is to people on larger, more fertile islands. With poor, rather infertile soil and only a few local food plants (taro, coconut, breadfruit, pandanus), the inhabitants have perforce had to become good fishermen. Recently, the use of rafts anchored offshore and of fish-aggregating devices (FADs) have increased the level of small-scale tuna fishing throughout the Pacific. Although data on subsistence fisheries in the Pacific Basin are sparse, the principal species taken appear to be tuna and tunalike fishes, wahoo, barracuda, mackerel, shark, great barracuda, sailfish, and dolphinfish, and reef, lagoon, and bottom marine animals, including clams and other invertebrates.

Countries in the region cooperate closely on fisheries matters through the South Pacific Forum Fisheries Agency (FFA), an association of 16 South Pacific island countries, which has permitted them to secure a fairer share of the benefits flowing from the exploitation of their tuna resources. Hawaii and the U.S. territories in the Pacific also cooperate on fisheries matters through the Western Pacific Regional Fishery Management Council, although the previous U.S. position on tuna hindered the Council's efforts to develop a management plan on tuna. A major new development in this area came in November 1990, when President Bush signed the Fishery Conservation Amendments of 1990, which will give the U.S. management authority over tuna in its EEZ, effective January 1, 1992.

With the rapid dissemination of information on resources of the tropical Pacific, there also came an era of introduction of new harvesting technologies, and intense rivalry and competition among fishing fleets. This is now particularly evident, for example, in Hawaii where a dispute erupted in the summer of 1989 between longline fishing vessels recently arrived from the U.S. mainland and a variety of local, small-scale trollers. This was a classic example of gear conflict that also raised questions about insular fishery interactions for tunas and other pelagics. Although the dispute has abated there is still considerable concern that few mechanisms exist for resolving long-term aspects of the conflicts.

Because of the tremendous growth of the domestic long-line fleet in Hawaii, the pelagic fisheries face the greatest regulatory pressure. In late 1990, and again in 1991, the WPRFMC proposed emergency regulations to limit the expansion of Hawaii's longline fleet. These regulations are currently in place and are expected to be extended for three years. Area closures around the main and Northwestern Hawaiian Islands have also been implemented.

FISHERY MANAGEMENT

The Western Pacific Regional Fishery Management Council (WPRFMC) is one of eight Councils established by the Magnuson Fishery Conservation and Management Act (MFCMA) to develop Fishery Management Plans (FMPs) and amendments for fisheries in the U.S. Exclusive Economic Zone (EEZ) around Hawaii and U.S. territories and other island possessions in the Pacific Ocean. After FMPs are approved by the Secretary of Commerce, they are implemented by federal regulations and enforced by the National Marine Fisheries Service and the U.S. Coast Guard in cooperation with state and territorial agencies.

As of this writing, the WPRFMC has four active FMPs:

1) FMP for the Crustacean Fishery of the Western Pacific Region, effective March 1983. Amendments implemented and projected through 1991: 6. The species included are the spiny lobster (*Panulirus marginatus* and *Panulirus penicillatus*) and the slipper lobster (*Scyllarides squammosus*).

2) FMP for the Precious Corals of the Western Pacific Region, effective, August 1983. Amendments implemented and projected through 1991: 1. All species of *Corallium* are included.

3) FMP for the Bottomfish and Seamount Groundfish Fisheries of the Western Pacific Region (replaces preliminary FMP for Seamount Groundfish Fishery Resources). Effective August 1986. Amendments implemented and projected through 1991: 3. Species included are: silverjaw jobfish (*Aphareus rutilans*); gray jobfish (*Aprion virescens*); squirrelfish snapper (*Etelis carbunculus*); longtail snapper (*Etelis coruscans*); bluestripe snapper (*Lutjanus kasmira*); yellowtail snapper (*Pristipomoides auricilla*); pink snapper (*Pristipomoides filamentosus*); yelloweye snapper (*Pristipomoides flavipinnus*); snapper (*Pristipomoides sieboldii*); snapper (*Pristipomoides zonatus*); giant trevally (*Caranx ignoblis*); black jack (*Caranx lugubris*); thick-lipped trevally (*Pseudocaranx dentex*); amberjack (*Seriola dumerili*); blacktip grouper (*Epinephelus fasciatus*); seabass (*Epinephelus quernus*); lunartail grouper (*Variola louti*);

ambon emperor (*Lethrinus amboinensis*); redgill emperor (*Lethrinus rubrioperculatus*); armorhead (*Pseudopentaceros wheeleri*); alfonsin (*Beryx splendens*); raftfish (*Hyperoglyphe japonica*).

4) FMP for Pelagic Fisheries of the Western Pacific Region, effective March 1987. Amendments implemented and projected through 1991: 0. The species included are the swordfish (broadbill) (*Xiphias gladius*); sailfish (*Istiophorus platypterus*); black marlin (*Makaira indica*); blue marlin (*Makaira nigricans*); shortbill spearfish (*Tetrapturus angustirostris*); striped marlin (*Tetrapturus audax*); mahimahi (*Coryphaena hippurus* and *Coryphaena equiselis*); wahoo (*Acanthocybium solandri*); and oceanic sharks (Carcharhinidae, Sphyrnidae and Lamnidae).

OVERVIEW OF ASSESSMENT APPROACHES

Because of legal responsibilities under the Magnuson Fishery Conservation and Management Act and the Marine Mammal Protection Act, stock assessments play a major role in the research program. Scientists at the Southwest Fisheries Science Center have a long history in the development of new assessment methodologies, with much of this work dating to the early days of the California Cooperative Oceanic Fisheries Investigations program in the late 1940s.

The SWFSC conducts stock assessments in support of many different agencies. Of particular importance, however, are the Pacific Fishery Management Council and the Western Pacific Regional Fishery Management Council, which rely on the technical expertise of Center analysts. Currently, there are SWFSC staff members on two Pacific Council plan monitoring teams (groundfish and anchovy) and four Western Pacific Council plan monitoring teams (bottomfish, crustaceans, pelagics, and precious corals). Staff members are also represented on the Scientific and Statistical Committees that serve the Councils. The technical expertise of population dynamicists at the SWFSC is used routinely by other agencies as well. SWFSC researchers have conducted stock assessments for the states of California and Hawaii, particularly in situations where local resources were limited. There is also the ongoing collaboration and cooperation between State and Center staff in the collection of fisheries data used in stock assessments. An example is the successful Fisheries Information Networks (Pacific = PACFIN; Western Pacific = WPACFIN), which provide an effective mechanism for the timely collection and distribution of basic fishery statistics to interested agencies. In this regard, Center staff have been involved in designing and establishing data collection procedures along the West Coast and throughout the Pacific region.

Center scientists also play a key role in stock assessments conducted in support of international agencies and commissions, including the Inter-American Tropical Tuna Commission (IATTC), the International Commission for Conservation of Atlantic Tunas (ICCAT), the South Pacific Commission (SPC), the International Whaling Commission (IWC), the International Union for Conservation of Nature (IUCN), the Commission for Conservation of Antarctic Marine Living Resources (CCAMLR), the South Pacific Albacore Research Group (SPAR), and the Food and Agriculture Organization (FAO) of the United Nations.

A traditional method of stock assessment is surplus production modeling, which examines catch and fishing effort over a period of years, usually in situations where detailed population data are sparse, as in many areas of the central and western Pacific. A case in point is the assessment of the Hawaii lobster fishery, which is presently managed using projections from a dynamic production model. Other examples of production models applied in specific assessments are the South Pacific albacore fishery, the billfish fishery in the western Pacific, and the multispecies bottomfish fishery in Hawaii.

Dynamic pool models, which provide a mathematical description of the yield from a fishery using data on fishing effort and catch as well as age and size composition, especially Beverton and Holt's yield per recruit formulation, are used routinely by Center analysts. There has been an awakening of interest in this type of analysis with the advent of spawning biomass per recruit as a criterion for defining overfishing. In addition, yield/recruit analysis has been utilized to assess the status of the snapper-grouper fishery in Hawaii, particularly in the main islands where equilibrium conditions are more nearly realized. Length-based methods of obtaining parameter estimates are a natural complement to dynamic pool models, particularly in the case where aging of large numbers of fish is not feasible. A number of assessments have been performed on tropical resources using these techniques to assess stocks of lobster, snappers, and deepwater shrimp.

More complex simulation models have been developed at the Center to assist in clarifying the complex interactions that can occur between fish, fishermen, and fisheries managers. For example, the Tuna Observer-Porpoise Simulation (TOPS) model has been developed to simulate the fishing pattern of the tuna purse seine fleet in the eastern tropical Pacific. The model incorporates spatio-temporal variability in the environment; tuna respond by aligning themselves in preferred habitat areas. The purse seine fleet then distributes itself in response to the distribution of tuna. By dynamically simulating the behavior of this system one can, for example, evaluate the bias in data collected on all aspects of the fishing operations by observers aboard tuna vessels.

The estimation of spawning biomass from fish egg and larval surveys is an area that the SWFSC has pioneered. Initially applied to the northern anchovy, the technique is also applicable to nehu, a small anchovy used as baitfish in the Hawaiian pole and line fishery for skipjack tuna. In this instance, spawning biomass was estimated weekly for 2 years and the relationship between stock size and the input of fresh water to Pearl Harbor was studied.

Researchers at the SWFSC also conduct a variety of other types of fishery-independent relative abundance surveys. Annual research trapping surveys of spiny and slipper lobster abundance in the Northwestern Hawaiian Islands are used to monitor patterns of recruitment and changes in size structure. Hook timers are one of the more innovative stock assessment techniques recently developed at the Center. This technology is an outgrowth of an assessment of armorhead stocks on North Pacific seamounts. Placed on bottom longlines, these devices allow measurement of time-to-capture for every fish that strikes a hook. This is particularly useful in situations where gear saturation or interspecific competition for baited hooks occurs.

Although fishery-independent relative abundance surveys are useful as auxiliary data, estimates of absolute abundance are much preferred. Resource surveys of deepwater shrimp and bottomfish conducted in Hawaii and the Northern Marianas derived total biomass estimates by conducting stratified catch per unit of effort (CPUE) sampling programs. These data were coupled with an estimate of catchability of the sampling gear obtained from depletion experiments on small, isolated populations.

Surveys of the relative abundance of marine mammals and endangered species are of special importance at the SWFSC. Virtually all of the many marine mammal assessments conducted at the Center are based on visual or photographic census data, whether obtained from aerial, vessel, or beach counts. Population estimates for the endangered Hawaiian monk seal have been based on beach counts of tagged seals, expanded to include offshore individuals. The same procedures have been used to obtain a population estimate of the threatened green turtle in Hawaii (i.e., expand counts of marked nesting turtles). Many of the techniques and methods of marine mammal population assessment developed by scientists at the SWFSC are among the most sophisticated in use in the world.

FISHERY LANDING TRENDS

Viewed from a national perspective,[1] the contribution of Hawaii's fisheries and seafood industry is relatively small. However, seafood and fisheries are extremely important culturally and socially in Hawaii, and both sectors have changed dramatically in recent years. The wholesale seafood market is almost \$120 million for a population of just 1 million people; there is a \$10-15 million charter boat industry, an equivalent tournament fishery, a recreational fishery valued at \$200 million (non-market values) and a commercial fishery that has more than doubled in the past 10 years, to \$50 million. The longline tuna fishery is the largest commercial fishery in Hawaii, valued at \$28 million in 1990. The smaller-scale troll and handline fisheries for tuna and mixed pelagics, such as mahimahi, are next in value, at \$7 million, while lobster, skipjack tuna (aku), and bottomfish are the other major commercial fisheries. (Figure 1.)

[1]In 1989, the commercial landings (edible and industrial) by U.S. fishermen at ports in the 50 states were a record 8.5 billion pounds (3.8 million mt), valued at \$3.2 billion in 1989-- an increase of 1.3 billion pounds (576,300 mt) in quantity, but a decrease of \$281.8 million in value compared with 1988. Aggregate statistics for U.S. fisheries are described in detail in **Fisheries of the United States, 1989.**

O'Bannon, Barbara K., ed. 1990. **Fisheries of the United States, 1989.** U.S. Department of Commerce, National Marine Fisheries Service: Fisheries Statistics Division. Current Fisheries Statistics No. 8900. Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402; (202) 783-3238.

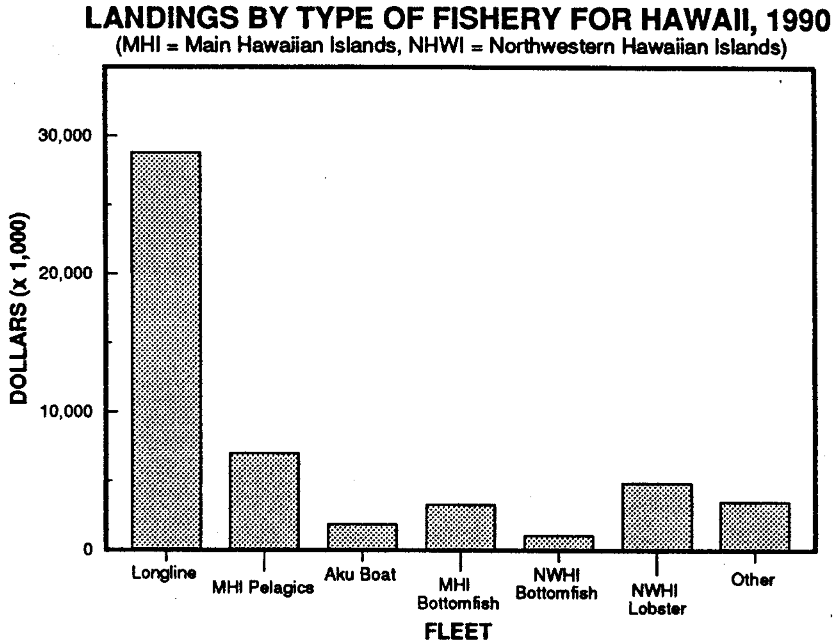


Figure 1.

Fishery-dependent data for the western Pacific are collected by three National Marine Fisheries Service elements: the Honolulu Laboratory's Fishery Management Research Program (FMRP), the Western Pacific Fishery Information Network (WPACFIN), and the NMFS Southwest Region's (SWR) field station in American Samoa. These data collection systems are a combination of mandated and voluntary logbooks, creel surveys, market sampling, and dockside interviews. Many exist through cooperative agreements with other fisheries agencies or with fishing vessels, seafood dealers, and brokers.

Since November 1990, logbooks are required of all domestic longline fishing vessels operating in the western Pacific. The logbooks include the usual daily catch and effort information as well as detailed descriptions of fishing area. The logbook program in Hawaii is conducted by the Honolulu Laboratory while arrangements are proceeding to cover any domestic longliners operating out of American Samoa, Guam, and the Northern Mariana Islands. Since January 1990, all data on landings by the foreign longline fleet operating out of Guam are monitored through cooperative agreements with Guam's port authority.

Technicians at the Honolulu Laboratory also conduct market monitoring of pelagic and bottomfish species in Hawaii through daily sampling at the Honolulu auction, detailed receipts data from dealers on the island of Hawaii, and from other major dealers and brokers. They also monitor landings by the small, Hawaii-based, pole-and-line skipjack tuna fleet. The WPACFIN assists the fisheries offices in American Samoa, Guam, and the Northern Mariana Islands in collecting similar information. In American Samoa, the SWR field station collects voluntary catch and effort logbooks from foreign albacore longliners off-loading in Pago Pago.

The Honolulu Laboratory staff not only collects data but are also primarily responsible for initially summarizing and reporting the information in quarterly reports for the longline and lobster logbook data and annual reports for the pelagic, bottomfish, and lobster fisheries. The annual reports are distributed to all permit holders and to the major seafood dealers in Hawaii. The WPACFIN data are summarized in Fisheries Statistics of the Western Pacific and circulated to the fisheries offices that provide the data and to about 50 other organizations and agencies in the region.

The following landings data were collected by the Southwest Fisheries Science Center's Honolulu Laboratory. Total landings of Hawaii's pelagic fishery were 18.5 million pounds worth $37.4 million in 1990. This represents a 14% increase in weight and a 24% increase in revenue from the previous year. There was also a 45% increase in landings, a 59% increase in nominal revenue, and a 36% increase in inflation-adjusted revenue over a 4-year period, 1987-1990 (Figure 2).

For all gear types combined, landings of Pelagic Management Unit Species (PMUS--billfishes, sharks, mahimahi, etc.) increased 64% while tuna landings decreased 10% in 1990 (skipjack landings have dropped 3.1 million pounds since 1988) (Figure 3). Landings of other pelagics remained at about the same level as in the previous year. Landings of other miscellaneous pelagics were very low in comparison to PMUS and tuna landings. Much of the increase in the PMUS category is due to swordfish landings which have increased from only negligible landings (seldom exceeding 50,000 pounds before 1988) to 3.4 million pounds in 1990. One of the significant changes in Hawaii's pelagic fishery in 1990 has been the great increase in swordfish landings, now estimated to equal longline landings of bigeye tuna. Recent entrants to Hawaii's longline fishery have been successful in targeting swordfish, although historically the primary target species of Hawaii's longline

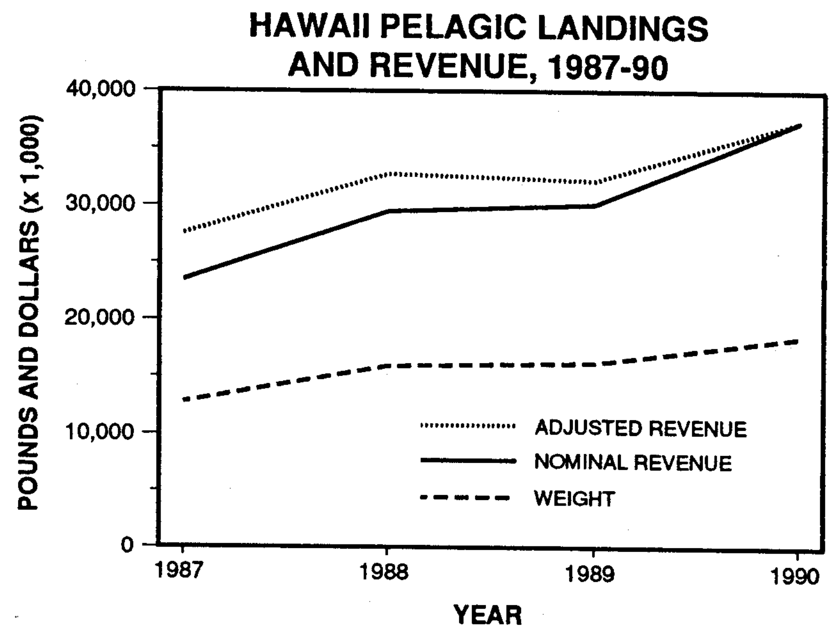


Figure 2.

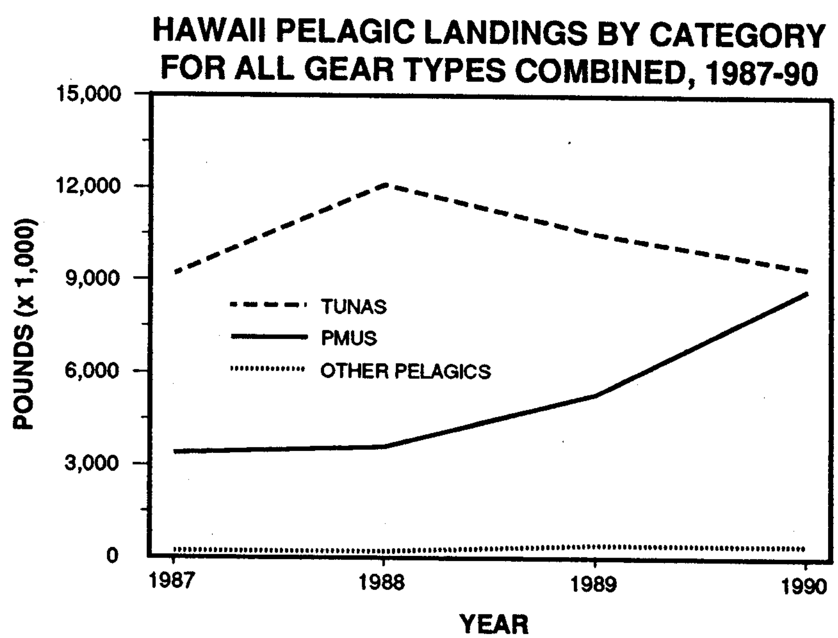


Figure 3.

fishery has been large bigeye tuna which still remains a dominant component of the longliners' catch.

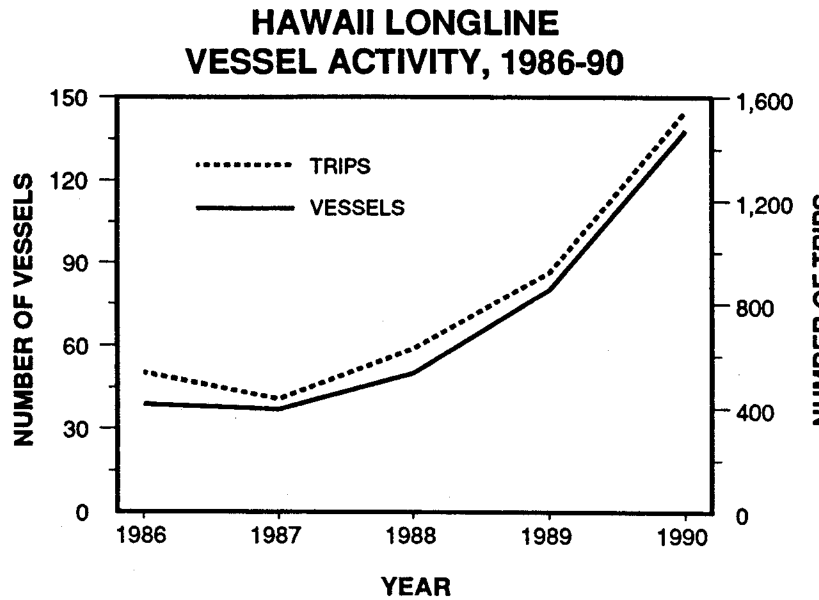


Figure 4.

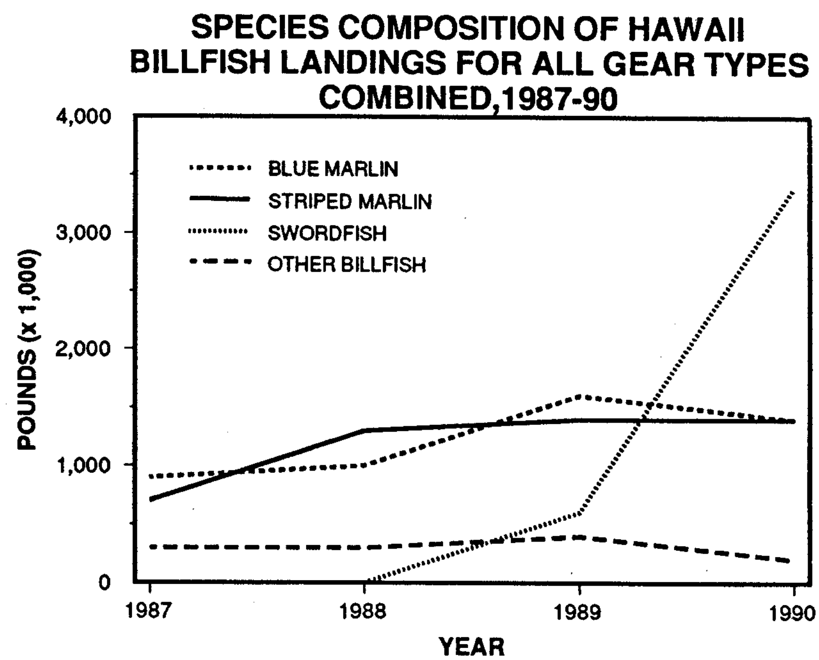


Figure 5.

Longline techniques used to target swordfish have greatly affected the landings of swordfish. Although longlining for swordfish was introduced in 1988, it was only during the early months of 1990 that most of the longline fleet did actually target swordfish. Longline landings of striped marlin and blue marlin remained at about the same level in 1990 while other billfish (shortnosed spearfish, black marlin, and sailfish) decreased slightly in 1990.

The longline fleet continued to expand in 1990, from 37 vessels in 1987 to 138 vessels in 1990 (Figure 4). As many as 51 boats from the Gulf of Mexico area and the U.S. west coast have entered the longline fishery; seven longline boats from the east coast were in Hawaii by the end of the year. Longline effort increased by 623 trips (up 67%) in 1990 (Figure 4).

For all gear types combined, swordfish landings increased 4.7 times over 1989 landings. Blue marlin and other billfish (shortnosed spearfish, black marlin, and sailfish) landings decreased, 13% and 50%, respectively, while striped marlin landings remained the same as in 1989 (Figure 5). Landings of swordfish showed the greatest increase over the 4-year period, increasing from only negligible amounts in 1988 to 3.4 million pounds in 1990. Blue marlin landings peaked in 1989 while striped marlin landings doubled during the 1987-1990 period. Landings of other billfish (shortnosed spearfish, black marlin, and sailfish) were small in comparison to the major billfish species.

Almost all of the billfish in the troll and handline category were caught by trollers. In 1990, troll and handline landings of blue marlin decreased 25%; landings of striped marlin, and other billfish (excluding swordfish) were quite low in comparison to blue marlin.

For all gear types combined, landings of mahimahi are highly seasonal and show substantial annual variation. In 1990, mahimahi landings increased 88%, while wahoo (known as ono locally) landings declined sharply and shark (mostly thresher and mako sharks) landings remained the same as in 1989 (Figure 6). Mahimahi landings have increased 200% since 1988, while wahoo land-

SPECIES COMPOSITION OF OTHER PMUS LANDINGS IN HAWAII BY LONGLINE, 1987-90

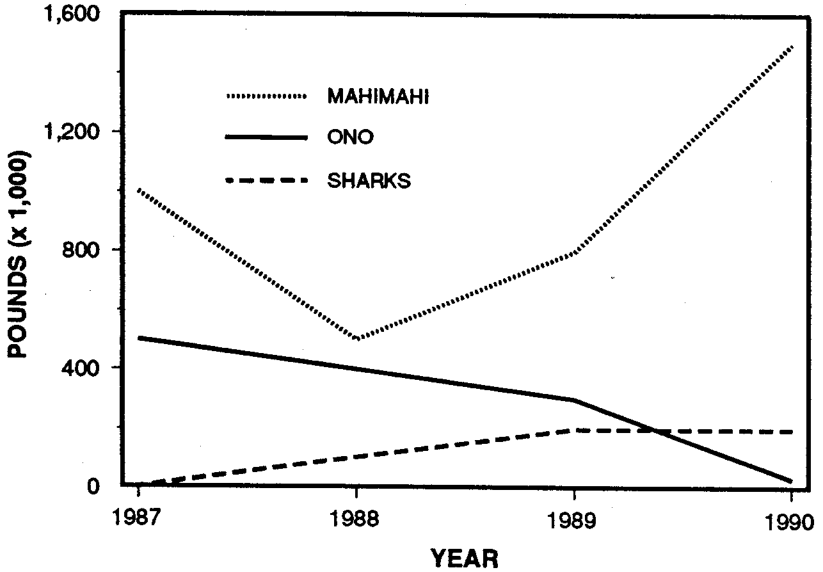


Figure 6.

SPECIES COMPOSITION OF HAWAII TUNA LANDINGS FOR ALL GEAR TYPES COMBINED, 1987-90

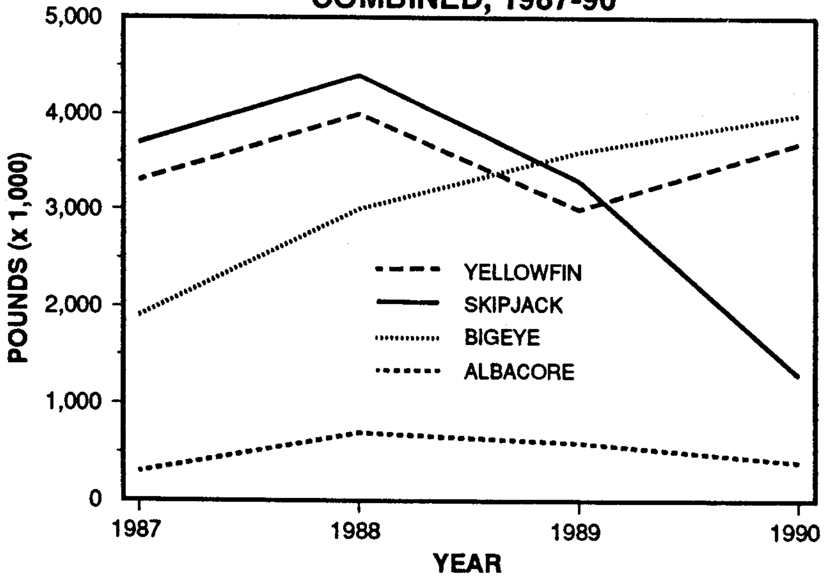


Figure 7.

ings decreased 40% since 1987. Shark landings are generally small or are not recorded since there is little commercial or sportfishing interest in sharks compared to the other PMUS. Sharks are, however, gaining acceptance in Hawaii's markets for fresh fish and in the recreational fisheries. Landings of sharks increased from negligible amounts to 200,000 pounds during the 4-year period, 1987-1990.

For all gear types combined, bigeye and yellowfin tuna landings increased in 1990, up 11% and 23%, respectively, while skipjack tuna and albacore decreased, down 61% and 33%, respectively, from 1989 (Figure 7). Landings of bigeye tuna increased 110% during the 1987-1990 period, while skipjack and albacore tuna landings declined during the same period.

Tuna landings by longliners and troll/handliners increased by 7% and 32%, respectively, while landings by the pole-and-line (skipjack) fleet decreased 67% in 1990 (Figure 8). Longliner tuna landings increased by 133% over the 4-year period while tuna landings by troll and handliners decreased by 47% from 1987-89, but increased 31% in 1990.

The longline landings of bigeye and yellowfin tunas increased 10% and 14%, respectively, while albacore landings decreased 33% in 1990 (Figure 9). Bigeye tuna landings increased 89% while yellowfin tuna landings more than tripled in 1987-1990. Albacore landings have decreased 43% since 1988. Troll and handline landings of yellowfin tuna have increased by 50% in 1990; bigeye tuna landings increased 20%; skipjack tuna landings remained at about the same level in 1990.

Troll and handline landings of yellowfin tuna decreased 70% from 1987 to 1989, but increased 50% in 1990. Bigeye tuna landings in 1990 have increased six times over 1987 landings. Troll and handline skipjack tuna landings averaged 300,000 pounds over the 4-year period, 1987-1990. Meanwhile the pole-and-line fishery for skipjack tuna has declined precipitously, due to a weak market, poor bait availability, and uneven catchability of the skipjack schools themselves.

Domestic and foreign pole-and-line (skipjack tuna) vessels and purse seiners are not subject to any permit or reporting requirements under the

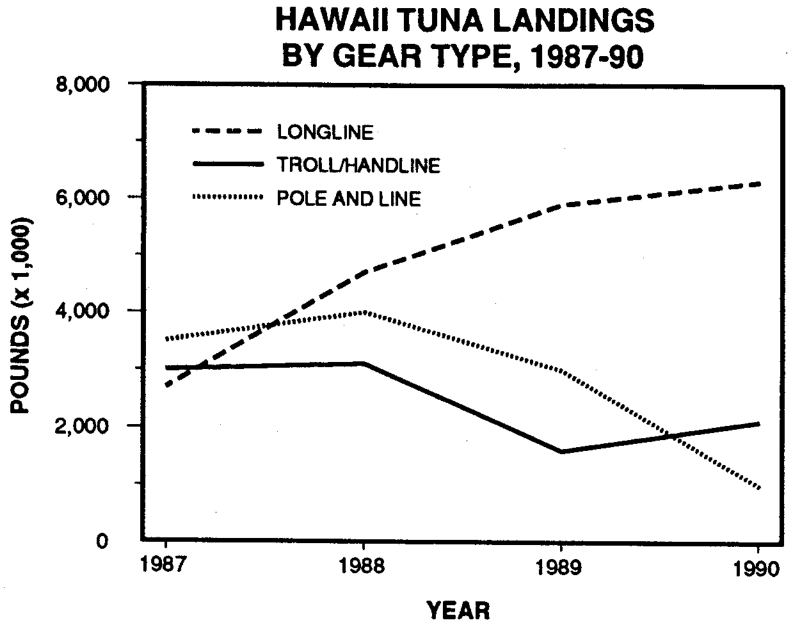


Figure 8.

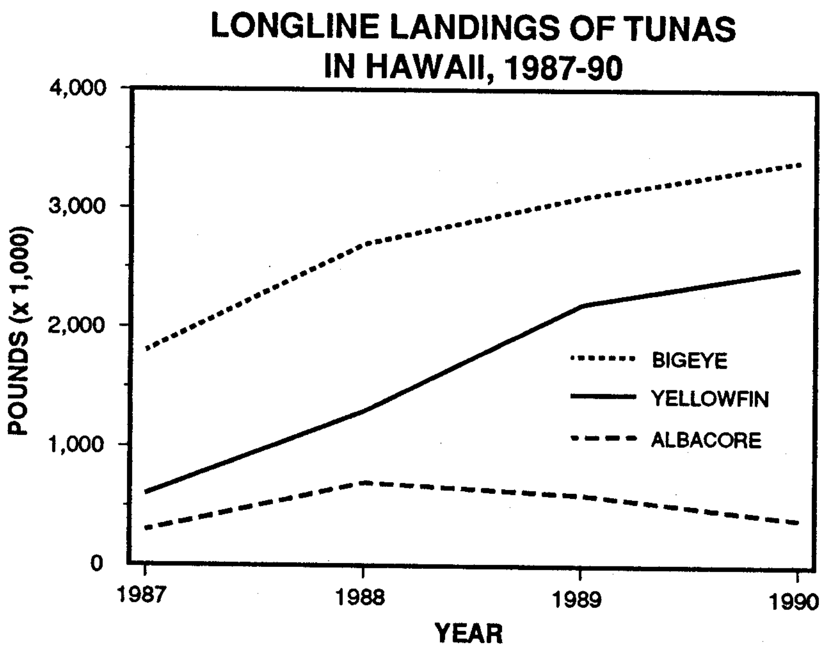


Figure 9.

present U.S. tuna policy, although this situation may change with the 1990 amendments to the Magnuson Act. Between 1982 and 1984 the annual average catch of skipjack tuna by Japanese pole-and-line vessels in the U.S. Exclusive Economic Zone (EEZ) (of the western Pacific region) was nearly 43 million pounds; less than 1% of the catch of Japanese pole-and-line vessels included non-tuna species.

For U.S. purse seiners in 1989, the western South Pacific area was the predominant location of catches of yellowfin and skipjack tunas for canners, accounting for 59% of the quantity of tuna taken by the U.S. fleet. This share grew tremendously during the 1980s, as it was only 6% of the total in 1980. The western Pacific became the leading production area in 1983 as a result of a shift in fishing effort caused by an unusually severe occurrence of the El Niño phenomenon. The bulk of the remainder of the U.S. tuna catch during 1986-1989 occurred in the eastern Pacific.

Yellowfin and skipjack tunas are the principal components of the purse seine catch which accounts for 95% or more of the total U.S. catch of tuna. Baitboats principally land yellowfin and skipjack tunas. U.S. trollers mainly land albacore and usually account for virtually the entire United States albacore catch. Albacore are not normally caught by purse seine vessels as this species is too scattered to be economically feasible as a target fishery for these vessels.

Because most U.S. tuna vessels operate beyond the 200-mile fishery zone claimed by the United States, U.S. vessels' fishery access is controlled primarily by foreign governments and international agreements negotiated with the United States. An example of such a multilateral agreement is one negotiated in 1986 between the United States and the South Pacific Forum Fisheries Agency (FFA). This region encompasses most of the grounds through which tuna stocks in the western Pacific migrate, and the western Pacific, as noted, is an important fishing area for the United States. The agreement basically provides for access by U.S. fishing vessels to the fishery zones claimed by FFA members, in return for which the vessels pay fees and the U.S. Government provides substantial assistance for economic development. The achievement of this agreement in 1986 ended several years of disputes over fishing rights, which included the seizure of U.S. fishing vessels by individual nations whose claims of national jurisdiction over tuna were rejected by the United States.

Among other provisions, the "Fishery Conservation Amendments of 1990," which reauthorizes and amends the Magnuson Fishery Conservation and Management Act allows the United States to exercise sovereign rights over tuna in the EEZ, calls for strengthened international management of tuna species, and establishes a system for management of domestic fishing for all highly migratory species--tuna, swordfish, billfish, and sharks. The bill is effective January 1, 1992, with the Western Pacific Regional Fishery Management Council retaining management authority in the Pacific.

COMMERCIAL FISHERY ECONOMIC TRENDS

General

The operative word to describe economic trends in the commercial fisheries of the central and western Pacific is **change**. Hawaii's commercial fisheries have grown dramatically since the mid-1970s and the use of western Pacific U.S. ports by domestic and foreign distant-water fishing vessels is growing. As a result, and in light of the relative size of the western Pacific EEZ, the fisheries in the Western Pacific Council's area of concern are growing in regional significance. On a per capita basis, these fisheries equal or exceed the value of fisheries to U.S. fishermen in most mainland states. Effort, landings, and value have been increasing rapidly in recent years as more offshore fishing grounds are being exploited by new, larger vessels and new technology. Furthermore, in the past 5 years, a fleet of 100-200 foreign longliners has begun operating out of Guam, airshipping fresh tuna directly to Japan.

Hawaii's commercial fisheries have grown dramatically since the mid-1970s....

The fisheries for spiny and slipper lobster now rank among the largest and most valuable fisheries in Hawaii, and there is growing interest in developing bottomfish fisheries in American Samoa, Guam, and the Northern Marianas. On the other hand, with the growth potential for some species coming to an apparent close (lobster and bottomfish in Hawaii), the needs for fishery management to optimize harvest levels have increased dramatically.

Albacore Trollers

Perhaps the first harbinger of these changes in Hawaii was the arrival of albacore trollers from the Pacific West Coast en route to newly discovered fishing grounds north of Midway Island late in the 1970s. While it had been expected that the albacore would be landed in Honolulu, most of the loads were transshipped to mainland canneries. However, some of the albacore trollers remained in Hawaii, and as the lobster fishery developed in the 1980s, they began to explore other fishery resources of the Northwestern Hawaiian Islands (NWHI). In the late 1980s and into the 1990s as many as 50 U.S. trollers were still involved in the South Pacific albacore fishery, with many of the boats in the fleet passing through Honolulu to and from the fishing grounds.

Lobster Fishery

A second major development was initiated in the 1970s after substantial quantities of lobster were discovered in the NWHI as a result of cooperative research by the NMFS, Hawaii Department of Aquatic Resources, University of Hawaii, and the U.S. Fish and Wildlife Service. By the mid-1980s, lobster was one of Hawaii's most lucrative fisheries. To develop the lobster fishery, new boats came to Hawaii, primarily from the Pacific Northwest. Large vessels, some over 100 feet in length with modern freezing and processing equipment, entered the fishery. New traps were developed which made fishing not only more efficient, but also allowed a second species of lobster, the slipper lobster, to be caught commercially. Although the first lobsters were sold locally, soon almost all were produced as a frozen tail product and sold to mainland U.S. buyers. This was the first premium product of Hawaii's new commercial fisheries, with prices ranging up to $13.50 per pound for the tails.

Bottomfish and Pelagics

The Northwestern Hawaiian Islands proved to be a good location for bottomfishing, which required boats similar to the early lobster boats. The expanding supply of snappers, opakapaka and onaga, made possible the expansion of the restaurant market by insuring a regular supply of fresh fish. At the same time, there was increased demand from the restaurant market for fresh mahimahi. Local wholesale dealers were able to promote fresh local mahimahi as a substitute for some of the large imports of frozen mahimahi. Since both bottomfish and mahimahi were landed fresh and sold primarily at the Honolulu auction, this marked a real change in the local fishery.

Finally, there was a revival of the traditional Hawaiian handline fisheries for tuna, using fuel-efficient small-scale vessels. This fishery, which targeted yellowfin tuna, was centered on the island of Hawaii but most of the product was shipped to Honolulu for the restaurant market. This was a fortuitous development for the neighbor islands which had not shared in the economic growth of Honolulu-based fisheries. Today, there are strong local markets for fresh fish on the neighbor islands, associated with the tourist trade and the considerable "exports" of fresh fish to the U.S. mainland.

In 1984, Hawaiian Tuna Packers, who dealt mainly in canned tuna products, closed as a result of major changes in the multinational tuna industry. The skipjack fleet declined, selling solely to the fresh market. An attempt to expand this market, especially to the U.S. mainland, is currently a major project of the Hawaii Department of Business and Economic Development. Fortuitously, this closure coincided with a dramatic rise in the market for fresh yellowfin and bigeye tuna. This, in turn, spurred the resurgence of Hawaii's longline tuna fleet, which produces a superior grade of yellowfin and bigeye tuna for sashimi. At around the same time, many bottomfish and lobster boats switched to longlining, as bottomfish and lobster catch rates declined and new, more efficient longline line-throwing technology developed. The exchange rates between the dollar and the yen also became more favorable, making tuna fishing more lucrative.

One result of the move toward fresh tuna has been a revitalization of the Honolulu auction which can now run over 8 hours. In the early 1980s perhaps as few as 15 vessels were fishing longline gear in Hawaii; presently, there are more than 125 vessels in the longline fleet. Most of the vessels are new and range in size from 65 to 95 feet, replacing the older and smaller sampans. The longline crews are diversifying, trying a number of different fishing strategies, such as fishing directly offshore as well as up to 1,200 miles from Honolulu; fishing for not only the highly-valued bigeye tuna but also the lower-valued but more abundant yellowfin tuna, and long-distance fishing for swordfish destined for export to the U.S. East Coast. These new vessels are also experimenting with new gear, including more efficient monofilament mainlines stored on reels and set by powered line throwers.

Presently, the market for fresh fish is highly competitive, with supply competition from Florida to Australia. The local fish market now competes with the market in Tokyo for the raw product and local consumers must compete with the demands of the local restaurant trade and the export market. In 1987, buyers from Japan began bidding at the Honolulu auction, signaling the dramatic expansion of Hawaii's longline tuna market, and in 1990, East Coast swordfish buyers began to establish permanent contacts and bases in Honolulu.

In 1979, Hawaii's Department of Land and Natural Resources predicted commercial fisheries growth to 50 million pounds in 1990 and 85 million pounds in the year 2000. The collapse of domestic U.S. production of canned tuna, however, was an unanticipated development in this equation and estimates of skipjack and albacore tuna were too high. Also expected was a more rapid development of the oceanic shrimp fishery which did not take place. However, the projections proved reasonable for yellowfin and bigeye tunas, lobster and bottomfish, and the prospects for further development remain strong, especially for tuna.

'Sport' Fishery

At this time the skipjack and yellowfin/bigeye tuna resources are perceived to have the greatest potential for expansion in the central and western Pacific, bringing new economic opportunities for the island nations. At the same time, local residents are worried about the nature of that growth. As an island state, a large percentage of Hawaiian residents fish, and the separation between "recreational" and "commercial" fishing is blurred. The only major study of the economics of recreational fishing in Hawaii was undertaken for NMFS by Meyer Resources, Inc. in 1987. Meyer estimated direct annual expenditures of \$24 million for the part-time commercial, subsistence, and recreational fisheries. The non-market value of these fishing trips to Hawaiian resident fishers was estimated at \$239 million; the total catch by these vessels was 21.4 million pounds, of which 47% was sold. The remainder was used for home consumption (23%), given away to friends and family (21%), or otherwise used. The Hawaii charterboat fishery was estimated at \$10 million in the mid-1980s, and tournament sport fishing is also a major component of the local economy. For these participants in Hawaii's fisheries, and even more so in American Samoa, Guam, and the Northern Mariana Islands, preserving traditional access to small-scale fisheries is an extremely important aspect of fisheries development and management. Thus it is not just a question of economic development but of social stability which must be considered in managing growth of the western Pacific fisheries.

Canned Tuna Fishery

Tuna fishing in the western Pacific has had a long history, during which time several well-established and successful fishing methods were developed. The introduction of large-scale purse seining, however, has raised uncertainties about how the stocks will be affected and how best to manage the fisheries. The growing aspirations of the Pacific island states to obtain a fair share of the revenues from the pelagic fisheries of their EEZs have added to the uncertainties. In spite of these doubts, the prognosis for further expansion of tuna fishing in the western Pacific is good for the U.S., although the size of the U.S. purse seine fleet declined for several years, from 90 in 1986 to 63 in 1989. However, with the announcement of the recent "dolphin-safe" policy of the U.S. canners, the eastern tropical Pacific (ETP) will be virtually abandoned by the U.S. tuna fleet after 1990, and the owners will have the option of either selling their boats or shifting to tuna fishing elsewhere.

According to industry sources, most of the vessels that have left the U.S. fleet in the ETP were sold to foreign-flag enterprises for use in the same tuna fisheries they fished in as U.S.-flag vessels. The 1984 El Niño, which occurred in the traditionally important eastern Pacific waters, also forced much of the fleet to move to the previously underexploited western Pacific tuna fishery. Fishing was so successful in the latter location that a large portion of the fleet remained even after the El Niño conditions dissipated. These changes in fleet location have also been affected by the shift in U.S. cannery capacity from southern California to Puerto Rico and American Samoa.

As to the future, at present there are few obvious causes for alarm with respect to the level of exploitation, although fundamental facts of tuna biology are not well understood. At this time there are no precise estimates of maximum sustainable yield, nor solid evidence for a decline in abundance of either yellowfin or skipjack tuna in the western Pacific.

One possible cloud on the horizon which may affect the future of the U.S. fleet in the Western Pacific is that of fishing access. This is an area where most of the fishing takes place within the 200-mile zone of other countries. The United States has an access agreement with 16 nations in the Western Pacific for as many as 50 U.S. boats under the South Pacific Tuna Treaty. Other nations fishing in that region now have access agreements as well--Japan, Taiwan, and Korea, for example. Many of the island states are concerned that fishing effort is at a maximum and there is an intent on the part of some of those states to limit licensing and perhaps even reduce the number of licenses that are available. If that takes place, then those U.S. boats that lose their licenses may have to go to the Indian or Atlantic Oceans to fish.

TRENDS FOR PROTECTED SPECIES

Certain protected species, as defined in the Marine Mammal Protection Act of 1972 and the Endangered Species Act of 1976, are among the present statutory responsibilities of the Southwest Fisheries Science Center. Those discussed in this report are: Hawaiian monk seal (*Monachus schauinslandi*); three stocks of spotted dolphin (*Stenella attenuata*); four stocks of spinner dolphin (*Stenella longirostris*); three stocks of common dolphin (*Delphinus delphis*); the Hawaiian green sea turtle (*Chelonia mydas*); and the Hawaiian hawksbill turtle (*Eretmochelys imbricata*).

Hawaiian Monk Seal

The Hawaiian monk seal is not only protected by the Marine Mammal Protection Act of 1972 but is also listed as "endangered" under the Endangered Species Act of 1976, following a 60% decline in number of seals observed on the beaches between the late 1950s and mid-1970s. The causes of this decline, as with many other animal populations, have been linked primarily to human disturbance of the breeding habitat of these seals. Few data exist on the number of monk seals before 1957, when all island populations were counted for the first time. The decline in monk seal numbers slowed in the 1970s. In 1980, the National Marine Fisheries Service began the process of designating "critical habitat" for monk seals, appointed a recovery team to develop a recovery plan, and began a program at its Honolulu Laboratory to conduct research on this species.

In 1986, critical habitat for these animals was designated and later extended in 1988 to include all of their breeding beaches in the Northwestern Islands and the waters around the islands up to a depth of 20 fathoms (including Maro Reef, a known foraging location). In 1981, priorities included population assessments and monitoring at the major breeding locations and recovery actions directed at the population at Kure Atoll, which had been depleted by 80% during the previous 20 years.

Certainly one of the bright spots in the recovery program is the Head Start Project, which has continued for the past 10 years and has now successfully reversed the decline in numbers. Female pups are captured and maintained under optimum conditions and then released at the end of their first summer. Survival of these pups, which might otherwise perish due to predation by sharks and harassment by adult male seals, has been high. The breeding potential of the population has also been strengthened by moving rehabilitated young female seals from French Frigate Shoals to Kure Atoll. The Kure Atoll population now contains a high proportion of immature seals, about two-thirds of which are female. Again, survival is high, auguring well for future growth.

Beginning in 1982, births at the breeding islands were monitored as an index of population status. Births increased through the mid-1980's, peaking at 226 in 1988. In 1989, births declined, followed by an even greater decline to 145 in 1990, probably the lowest number of births per year during the last decade. Except at Kure Atoll, the 1989-90 decline in births was evident throughout the Northwestern Hawaiian Islands. Similarly, total beach counts of seals generally increased through the 1980s, but then dropped slightly in 1990.

The bottom line is that 10 years of effort at Kure Atoll appears to be leading that population toward recovery. Identification of the causes of the attacks by groups of adult males on individual adult females (and occasionally younger animals of either sex)--the "mobbing" problem--at Laysan and Lisianski Islands and the development of a practicable solution to reduce female mortality continue under investigation. Protection from future fisheries impacts is critical to recovery.

Dolphins

As is well known, a common way to locate yellowfin tuna schools in the eastern tropical Pacific Ocean is to search for schools of dolphins because there is often a school of tuna swimming just below them. In the process of encircling the tuna, a small percentage of the schooling dolphins may also become entrapped in the net (the majority of dolphins, more than 99%, escape). After being brought to the vessel, the dead dolphins are discarded. The incidental catch of dolphins is generally an isolated problem, affecting only the harvest of eastern tropical Pacific tuna.

This incidental catch of dolphins has long been of concern among animal-rights groups, a growing portion of the general public, Congress, and government agencies. In the 1960s the incidental catch of dolphins by U.S. purse seiners increased significantly with the explosive growth of the purse seine fleet. The Marine Mammal Protection Act (MMPA) was enacted by Congress in 1972 in response to public concern that certain marine mammal populations, including dolphins, were being harvested in such numbers (the best available figures indicate that 300,000 to 400,000 died annually in tuna purse seine nets) that they risked overexploitation. Under the authority of the MMPA, the Administrator of the National Oceanic and Atmospheric Administration (NOAA), parent agency of the National Marine Fisheries Service, is empowered to close the U.S. eastern tropical Pacific tuna purse seine fishery when such tuna harvesting results in a bycatch of dolphins exceeding a set annual quota. Beginning in 1977, the Administrator of NOAA authorized an annual dolphin quota of 20,500 animals for U.S. fishermen. The U.S. industry first approached this quota in 1986, when for the first time the Administrator ordered the closure of the eastern tropical Pacific fishery beginning October 21, 1986, and continuing through the remainder of the year.

When the MMPA was passed by Congress in 1972, the Southwest Fisheries Science Center broadened an existing research project started in 1970 on dolphin population biology, and started new projects designed to reduce fishing mortality and to estimate trends in dolphin abundance so that a rational management plan could be devised. Currently, the SWFSC has a large research program devoted to the life history and population dynamics of dolphins. Using two NOAA research vessels, in 1990 the Center completed the fifth year of an extensive survey program censusing dolphin populations in the eastern tropical Pacific, an area of roughly 6.5 million square miles. The objective was to collect information necessary to estimate the relative density, distribution and ecology of the dolphin stocks over a given time period. Overall analyses of dolphin populations so far have detected no trends in population abundance for any of the fishery-affected stocks. However, the margin of error is large for these research vessel surveys since they cover such vast areas of ocean and survey animals that are not randomly distributed. A report to the Congress in 1992 on the status of these dolphins will be based upon both the results of the vessel surveys and on past environmental and observer data from tuna vessels to improve the reliability of the analysis.

A significant development in the dolphin story came in April 1990 when the three largest U.S. tuna canners announced, in response to continued pressure from environmentalists and animal-rights groups, that they would no longer buy tuna harvested using methods that endangered dolphins. Under the so-called "dolphin-safe" policy, canners would purchase frozen tuna only if certified observers confirmed in writing that the vessel made no net sets in association with dolphin during the fishing trip. In addition, they announced that they would purchase no tuna caught with gillnets or driftnets (nets designed to catch albacore but which may also catch other species, including marine mammals).

This action on the part of U.S. canners hastened the exodus of the U.S. fleet which had been gradually leaving the ETP because of what they saw as restrictive government rules and regulations governing fishing on tuna associated with dolphins. With the virtual disappearance of the U.S. fleet from the tuna purse seine fishery in the eastern tropical Pacific, the emphasis on reducing dolphin mortality has now shifted to the international fleet in the ETP. The tuna harvesting nations of the ETP met in Costa Rica in September 1990 and reaffirmed their commitment to a dolphin program with the following objectives: Over the short term, reduce dolphin mortality significantly and over the long term bring dolphin mortality to insignificant levels approaching zero. Further, the fishing nations agreed to undertake research programs to modify the current purse seining technology to improve its efficiency, to reduce dolphin mortality, and at the same time undertake research to develop alternative methods of fishing dolphin that would eliminate dolphin mortality entirely. It also called on the nations to carry observers on all boats. The Inter-American Tropical Tuna Commission (IATTC) was designated to serve as a technical body for this program and the director of the IATTC was asked to convene a technical meeting to study various ways that could be utilized to attain the above objectives.

The implementation of these actions, while wholly commendable, has now produced essentially a Catch-22 situation. On the one hand, it became apparent that the dolphin kill rate criteria in the Marine Mammal Protection Act, as amended, have been difficult for other countries to meet. Since most of the U.S. fleet has left the ETP, due in large part to the dolphin-safe policies of the tuna canning industry, there is only a much-lowered fishing standard on which to base comparative criteria for other tuna fishing nations who fish in the ETP.

Speculations by all parties concerned on the possible resulting scenario have focused on the fact that, if pressured, the countries fishing in the ETP would be driven away from the international program to the great detriment of the dolphins. At this point it appears that it is essential to keep some type of multinational effort directed at the problem of dolphin mortality in the ETP. The alternative may be that if some of these options are closed to the international fleet, it will move in the direction of its own perceived self-interest and ignore the U.S. dolphin programs.

Hawaiian Green Turtle

The Hawaiian green turtle is listed and protected under the U.S. Endangered Species Act as either "threatened" (in Hawaii and elsewhere worldwide) or "endangered" (in Florida and on the Pacific coast of Mexico). Green turtles worldwide are also listed on Appendix I of the Convention on International Trade in Endangered Species of Fauna and Flora. Prior to their protection under State and Federal laws, Hawaiian green turtles were exploited for food and commerce. Considerable harvesting of nesting and basking turtles took place at French Frigate Shoals, where turtles were killed and shipped to markets in Honolulu up until at least the 1950s.

A draft recovery plan, as required under the U.S. Endangered Species Act, has been prepared for the Hawaiian green turtle by a recovery team appointed in 1985. This plan serves as the operational guidelines, pending development of a Pacific-wide recovery plan for marine turtles.

Hawksbill Turtle

The hawksbill is considered by many authorities to be the most endangered of all marine turtles because of continuing international trade in tortoiseshell. This turtle is listed and protected under the U.S. Endangered Species Act as an "endangered" species. In addition, it is included on Appendix I of the Convention on International Trade in Endangered Species of Fauna and Flora. In the Hawaiian Islands, the hawksbill is presently a rare species that is believed to be in immediate danger of extinction. Overall there may not be more than 15 hawksbills nesting annually on all the Hawaiian beaches where nesting is known to take place.

There is little information on aspects of the life history and ecology of this turtle. A draft recovery plan, as required under the U.S. Endangered Species Act, has been prepared for the Hawaiian hawksbill by a recovery team appointed in 1985.

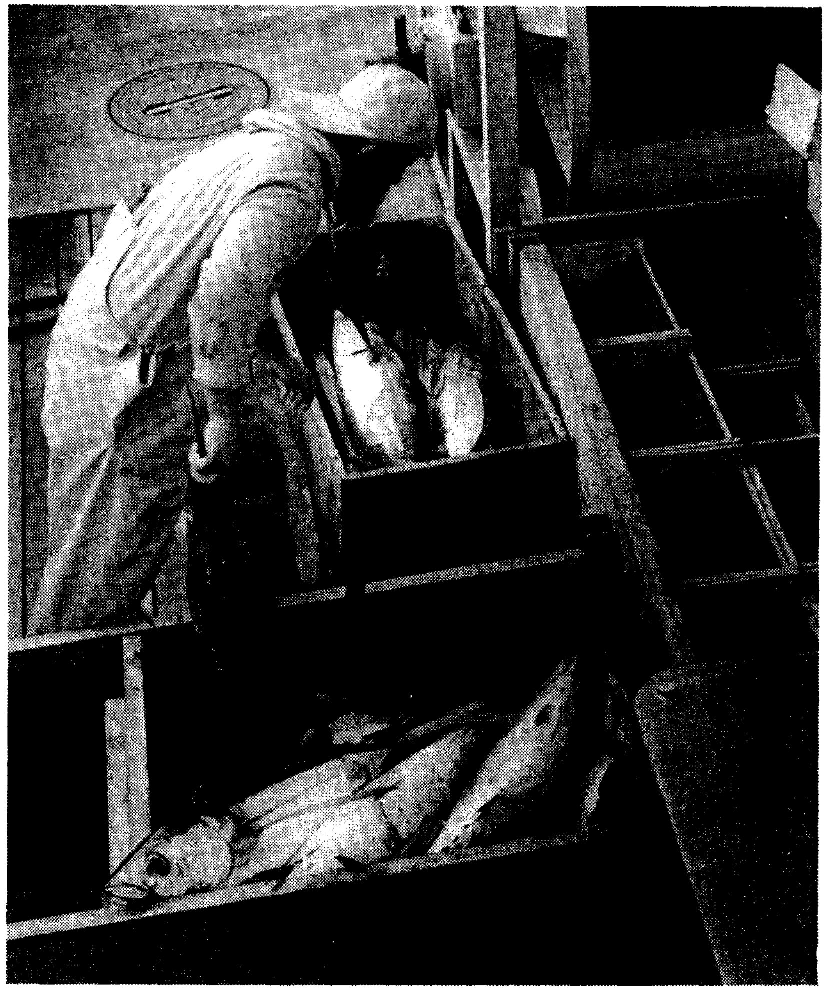
Scientists at the Honolulu Laboratory are currently conducting research to address needs outlined in an interim Hawaiian Sea Turtle Recovery Plan. This interim plan will be incorporated into a Pacific-wide Turtle Recovery Plan, now being compiled by the NMFS Southwest Regional office and scheduled for completion in June 1993.

SPECIES SYNOPSES

The synopses of information on the status of the stocks of the 18 species or groups of species presented in this section are based on commercial and recreational fishery data and on research data, as described in the Introduction to this report. The synopses are arranged by the major groups described earlier (large pelagics, insular species, marine mammals, and sea turtles.) and include information on the marine stocks managed under Fishery Management Plans, as well as protected species and migratory pelagics. In general, the summaries present key elements of basic life history, description of the fishery, magnitude of landings, stock condition, effectiveness of current management, and projected future status; also included are historical landings summaries in graphic form. For protected or endangered species, the information emphasizes abundance levels rather than catches and fishing mortality rates.

1. SOUTH PACIFIC ALBACORE

The albacore, *Thunnus alalunga*, is an oceanic scombroid found in the Pacific, Atlantic, and Indian oceans. In the Pacific it occurs in two populations occupying the Northern and Southern Hemispheres. There is no evidence of mixing between the North Pacific and South Pacific albacore populations, and the evidence of differences between them is considerable. Hence, they are treated as separate stocks for management purposes. Similarly, albacore in the Indian Ocean is considered to be a separate stock from South Pacific albacore although there is little confirming evidence. The South Pacific albacore stock ranges from equatorial waters to the southern boundary of the Subtropical Convergence Zone (STCZ, approximately 35-40°S) and between the South American coast and Tasmania.



Longlining for albacore.

The limited data available indicate that South Pacific albacore spawn in subequatorial waters between 10° and 20° south latitude primarily from November to April. Juveniles first recruit to surface troll and drift gillnet fisheries in the STCZ at about 45 cm fork length (FL) (18 in, 5 lb, age 1.5 years). Maturity is reached at 80-90 cm FL (32-35 in, 25-35 lb, age 5-6 years). The largest South Pacific albacore, about 120 cm FL (47 in, 70-80 lb, age approximately 12 years), are caught by the longline fishery. The distribution of catchable-sized albacore varies seasonally. During July-November they appear to inhabit primarily the lower and middle latitudes, then extend their range to the STCZ during the southern summer. Albacore favor sea temperatures in the range of 15-20°C, and their distribution and availability are closely linked to oceanographic conditions. Higher catch rates are expected in areas with a relatively shallow mixed layer and sharp temperature gradient.

South Pacific albacore exploitation began in 1952 with the post-World War II expansion of Japan's distant-water tuna longline fleet. U.S. canneries were built at Pago Pago, American Samoa, to process the catch of Japanese vessels based there. Longliners from the Republic of Korea and the Republic of China

(ROC, Taiwan) entered the fishery in 1958 and 1963, respectively, also landing a significant share of their catch in Pago Pago.

During the late 1960s, the Japanese longline fleet began to divert fishing effort from albacore to bigeye tuna and southern bluefin tuna and withdrew from South Pacific bases. Their albacore catch declined as the catch by Korean and Taiwanese longliners grew. During the two decades between 1968 and 1987, the total annual longline catch fluctuated between approximately 21,000 mt and 38,000 mt, averaging about 32,000 mt, with no long-term trend. The longline fishery harvests primarily large, mature albacore exclusively for canning.

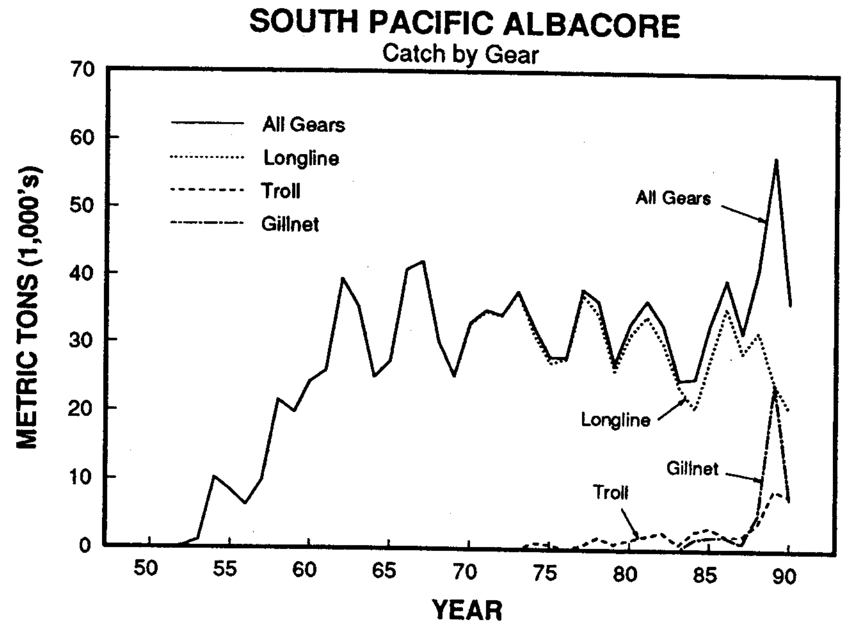


Figure 10. South Pacific albacore catch by gear type.

Surface fishing yields mostly small, immature albacore. Until the early 1980s, the surface catch of South Pacific albacore was minor; coastal trollers and sportfishing boats in New Zealand and Australia landed 2,500 mt or less each year. During the 1980s, prospects for expanding surface albacore fisheries into offshore waters of the STCZ were explored by research vessels and commercial fishing interests from Japan, France, United States, New Zealand, and Taiwan. By the 1988-89 surface fishing season (November-April) over 9,000 mt of albacore were being caught in offshore STCZ grounds by drift gillnet fleets from Japan and Taiwan and a troll fleet from the U.S. (primarily), New Zealand, and Canada. As both gillnet and troll fleets expanded further in the 1988-89 season, the surface catch exploded to nearly 33,500 mt, including about 24,500 mt taken by gillnet vessels. The total 1989 catch, including about 24,500 mt caught by longliners and small amounts by other surface gear, rose to a record 57,824 mt, worth approximately US $115 million ex-vessel. Most of the surface catch, including all of the drift gillnet catch and U.S. troll catch, has been taken in international waters beyond the jurisdiction of South Pacific island states. The longline catch, however, is taken both in international waters and within South Pacific 200-mile exclusive economic zones.

Regional concerns quickly arose over the ecological effects of drift gillnet fishing and the impacts of the increased surface catch, primarily by gillnet vessels, on the South Pacific albacore stock and the established longline fisheries. In November 1989, South Pacific delegates met in Wellington, New Zealand, to adopt a convention prohibiting the use of drift gillnets in the South Pacific region by signatory nations and discouraging use of the gear by others. In response, Japan and Taiwan reduced their South Pacific driftnet fleets by two-thirds in the 1989-90 fishing season and the driftnet catch declined (Figure 10). Korea announced that it would cease exploratory driftnet fishing in the region and not pursue driftnet fishery development plans.

In December 1989, U.N. General Assembly Resolution 44/225 was issued, supported by South Pacific nations, Japan, and the United States, calling for a moratorium on South Pacific drift gillnet fishing by July 1, 1991, to be in effect until appropriate conservation and management arrangements for South Pacific albacore are established. Subsequently, Japan announced a total withdrawal of its drift gillnet fleet from the region one year in advance of the moratorium date. Taiwan, its fishing season already completed by the July 1 deadline, has said it will comply with the moratorium.

Until the recent expansion of surface fisheries, assessment of the South Pacific albacore stock focused on the adult segment of the population targeted by the longline fleet. Catch and catch per unit effort (CPUE) statistics suggested a steady decline in the adult stock as the longline fishery developed. Production models fitted to historical longline catch and CPUE statistics in the late 1970s and early 1980s indicated a maximum sustainable yield

Table 1. Estimated South Pacific albacore catch (1000's metric tons) by year and fishing method, 1981-1990.

Fishing method	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Longline	34.24	30.27	23.84	20.64	27.87	35.63	28.77	31.91	24.38	20.60
Gillnet	0	0	0.03	1.58	1.93	1.94	0.92	5.27	24.45	7.57
Troll	2.08	2.43	0.74	2.77	3.25	2.01	1.98	3.93	8.90	8.01
Other	0.20	0.20	0.20	0.10	0.10	0.20	0.20	0.20	0.20	0.20
TOTALS	36.53	32.90	24.82	25.10	33.15	39.68	31.77	41.21	57.82	36.28

for the longline fishery of 33,000-35,000 mt/year (Table 1) in the presence of the small (ca. 2,000 mt/year) surface fishery prevailing then. Thus, the longline fishery yield was considered to be at its maximum sustainable level (Table 2). Because of inadequate data and lack of knowledge of South Pacific albacore population dynamics, there are no reliable estimates of the potential aggregate yield from all fisheries or the effects of higher surface catches on longline catch rates. However, further reductions in longline CPUE are expected due to expanded surface fisheries. In addition to concerns over surface-longline fishery interactions, questions exist about the effects of further spawning stock reduction on recruitment.

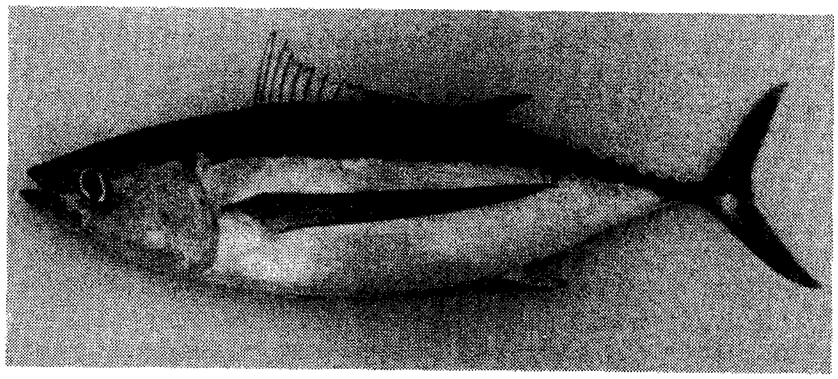
In 1986, scientists from the United States (NMFS), New Zealand, France, Japan, Taiwan, Korea, the South Pacific Commission Tuna and Billfish Program, and various South Pacific nations established the South Pacific Albacore Research (SPAR) group. The informal SPAR arrangement provides for exchange and compilation of South Pacific albacore fishery data and for collaboration in fishery monitoring, stock assessment, and research. SPAR workshops have been convened in New Zealand (1986), Fiji (1989), and New Caledonia (1990). The SPAR group successfully promoted cooperative oceanographic and albacore trolling surveys in the STCZ, albacore tagging programs, and studies of albacore age and growth and reproductive biology. Research is being conducted by the staff at the Honolulu Laboratory and the South Pacific Commission to develop a length-age structured model of stock and fishery dynamics for assessment of yield potentials and fishery interactions.

In tandem with the Wellington Convention on drift gillnets, government and industry officials from the South Pacific region and distant-water fishing nations have met in New Zealand, Fiji, Solomon Islands, and New Caledonia to exchange views on a South Pacific albacore management regime. Such talks are continuing, and scientific guidance is being provided by SPAR.

Table 2. Resource Summary- South Pacific albacore.

Average catch (1988-90)	=	45,000 mt
Long-term potential catch:		
-Longline fishery MSY with 2,000 mt surface fishery (estimated by production model)	=	33,000-35,000 mt
-Potential yields for other fishery scenarios	=	Unknown
ABC (1990)	=	>35,000 mt
Importance of recreational fishery	=	Minor
Management	=	Multilateral regime under discussion
Status of exploitation	=	Unknown overall, but adults appear to be fully exploited
Size at 50% recruitment	=	60 cm- surface 90 cm- longline (male and female)
Size at 50% maturity	=	85-90 cm (male and female)
Assessment approach	=	Production model applied to longline gear taking adults; age-based models for more comprehensive assessments under dev.
Fishing strategy	=	None
F (1990)	=	Unknown
M= 0.2	**$F_{0.1}$= Unknown**	**F_{max}= Unknown**

2. NORTH PACIFIC ALBACORE



The North Pacific albacore resource is considered to be a separate stock from the South Pacific albacore, based on tagging and fishery data. The northern stock is among the best understood of the Pacific tunas. Adults (ages 5 to at least 10 years; ≥85 cm fork length, FL) are distributed from the North Pacific Transition Zone (NPTZ), (mixing zone between the subarctic and subtropical fronts) approximately between 35°N latitude and 43°N latitude, to the equator, with concentrations in a band between 35°N and 10°N latitude. Juveniles are distributed from Asia to North America, mostly in the NPTZ.

Spawning in the North Pacific takes place during the summer in the subtropical areas between 10°N and 20°N latitude. Samples of small albacore suggest that recruitment to the fisheries may occur principally off Japan in the spring and to a lesser extent in other areas.

Juvenile albacore make extensive annual migrations between Japan and North America. In general, it appears that the bulk of the juvenile albacore recruiting into the North Pacific fisheries first enter the Japanese western Pacific fisheries off Japan and then move eastward. Tagging of juveniles (ages 1 to 5) indicates fish tagged off Japan appear in the North American fishery, moving across the NPTZ. Albacore tagged off North America appear to move across the Pacific during the fall and are recaptured in the Japanese late winter/spring fisheries near Japan. These fish then migrate back to North America. There are few returns of mature fish. Some of the albacore may recruit to North America in the spring and then follow the migration pattern described.

Albacore (>30 cm FL), remain in the upper trophic level feeding opportunistically on squid, crustaceans and small fish. Known principal predators include sharks and billfishes. Albacore appear to compete for food with sharks, billfishes, other tuna, and others including marine mammals.

The dynamics of the albacore population are not completely understood. The instantaneous natural mortality rate, M, is thought to be between 0.2 and 0.4. Maximum size, L infinity, is approximately 120 cm FL. This corresponds to a maximum age in the unexploited population of approximately 12 years. Size at maturity is approximately 85 cm (age 5+). Fecundity is estimated to be between 0.8 to 2.6 million eggs per spawning cycle (year), substantially less than for tropical tunas.

Table 3 shows the catch history of North Pacific albacore by gear and country.

In the North Pacific, albacore are fished primarily by longline (Japan, Taiwan, and Korea), pole-and-line (Japan), drift gillnet (Japan, Taiwan, and Korea) and by trolling (U.S.). The longline gear is operated in the lower latitudes. This gear accounts for about 20% to 25% of the current catches. All the surface gear are operated in the more temperate regions and account for 75% to 80% of the reported catches.

The U.S. fishery in the North Pacific extends from the mid-North Pacific to North America. The number of U.S. vessels varies depending on the year, from about 300 to 2,000; many of which also fish salmon and other species. The U.S. fishery has operated on the stock since the early part of the century. Albacore is a major target for both the private rec-

Table 3. Catches of North Pacific albacore in metric tons by fisheries, 1952-1990.

YEAR	JAPAN						TAIWAN		KOREA[1]	UNITED STATES						CANADA	GRAND TOTAL
	Bait[2]	Long[3] line	Gillnet	Purse Seine	Other Gear	Sub Total	Long Line	Gillnet[4]	Long Line	Bait	Troll[5]	Sport	Gillnet	Purse Seine	Sub Total	Troll	
1952	41,786	26,687		154	237	68,864					23,843	1,373			25,216	71	94,151
1953	32,921	27,777		38	132	60,868					15,740	171			15,911	5	76,784
1954	28,069	20,958		23	38	49,088					12,246	147			12,393	-	61,481
1955	24,236	16,277		8	136	40,657					13,264	577			13,841	-	54,498
1956	42,810	14,341		-	57	57,208					18,751	482			19,233	17	76,458
1957	49,500	21,053		83	151	70,787					21,165	304			21,469	8	92,264
1958	22,175	18,432		8	124	40,739					14,855	48			14,903	74	55,716
1959	14,252	15,802		-	67	30,121					20,990	0			20,990	212	51,323
1960	25,156	17,369		-	76	42,601					20,100	557			20,657	5	63,263
1961	18,636	17,437		7	268	36,348				2,837	12,061	1,355			16,253	4	52,605
1962	8,729	15,764		53	191	24,737				1,085	19,760	1,681			22,526	1	47,264
1963	26,420	13,464		59	218	40,161				2,432	25,147	1,161			28,740	5	68,906
1964	23,858	15,458		128	319	39,763	26			3,411	18,392	824			22,627	3	62,419
1965	41,491	13,701		11	121	55,324	261			417	16,545	731			17,693	15	73,293
1966	22,830	25,050		111	585	48,576	271			1,600	15,342	588			17,530	44	66,421
1967	30,481	28,869		89	520	59,959	638			4,113	17,826	707			22,646	161	83,404
1968	16,597	23,961		267	1,109	41,934	698			4,906	20,444	951			26,301	1,028	69,961
1969	32,107	18,006		521	1,480	52,114	634			2,996	18,839	358			22,193	1,365	76,306
1970	24,376	15,372		317	794	40,859	1,516			4,416	21,041	822			26,279	354	69,008
1971	53,198	11,035		902	367	65,502	1,759			2,071	20,537	1,175			23,783	1,587	92,631
1972	60,762	12,649	1	277	646	74,335	3,091			3,750	23,608	637			27,995	3,558	108,979
1973	69,811	16,059	39	1,353	533	87,795	129			2,236	15,667	84			17,987	1,270	107,181
1974	73,576	13,053	224	161	959	87,973	570			4,777	20,187	94			25,058	1,207	114,808
1975	52,157	10,060	166	159	254	62,796	1,494		319	3,243	18,975	640			22,858	101	87,568
1976	85,336	15,896	1,070	1,109	285	103,696	1,251		971	2,700	15,932	713			19,345	252	125,515
1977	31,934	15,737	688	669	379	49,407	873		65	1,497	10,005	537			12,039	53	62,437
1978	59,877	13,061	4,029	1,115	2,097	80,179	284		174	950	16,682	810			18,442	23	99,102
1979	44,662	14,249	2,856	125	1,158	63,050	187		27	303	6,801	74			7,178	521	70,963
1980	46,743	14,743	2,986	329	1,209	66,010	318		15	382	7,574	168			8,124	212	74,679
1981	27,426	18,020	10,348	252	904	56,950	339		600	748	12,694	195			13,637	200	71,726
1982	29,615	16,762	12,511	561	732	60,181	559		1,070	425	6,661	257			7,343	104	69,257
1983	21,098	15,103	6,852	350	125	43,528	520		1,233	607	9,512	87			10,206	225	55,712
1984	26,015	15,111	8,988	3,380	518	54,012	471		1,041	1,030	9,378	1,427		3,728	15,563	50	71,137
1985	20,714	14,320	11,204	1,533	407	48,178	109		2,169	1,498	6,431	1,176	2	-	9,107	56	59,619
1986	16,096	12,945	7,813	1,542	650	39,046	-			432	4,708	196	3	-	5,339	30	44,415
1987	19,091	14,642	6,698	1,205	189	41,825	-	7,700		158	2,766	74	5	-	3,003	104	52,632
1988	6,216	13,904	9,074	1,208	177	30,579	38	11,366		598	4,212	64	15	-	4,889	155	47,027
1989	8,629	12,899	7,437	2,521	1,421	32,907	504	4,200		54	1,860	160	4	-	2,078	200	39,889
1990[6]	12,500			2,315		14,815				115	2,603	24	29	71	2,842	305	17,962

1. Korean gillnet catches are missing. Korean longline catches calculated from FAO statistics and Korean catch/effort data.
2. Japanese bait catches include fish caught by research vessels.
3. Japanese longline catches for 1952-60 exclude amount taken by vessels under 20 tons. Longline catches in weight are estimated by multiplying annual number of fish caught by average weight statistics. Catches from 1958-68 were readjusted in 1988.
4. Taiwanese gillnet catches are personal communication from Institute of Oceanography, National Taiwan University.
5. U.S. troll catches from 1952-60 include fish caught by baitboats; from 1961-85 include fish landed in Hawaii. U.S. troll catches (1984-88) include gillnet
6. Figures for 1990 are preliminary.

reational fishermen and the commercial party boats operating in southern and central California waters. In years when abundance was high, in excess of 1,000 mt was landed by recreational fishermen. In recent years albacore has not been as available.

Based on an ex-vessel value of $2,200 per mt the annual value of the 1980-90 average annual catch of North Pacific albacore is about $121 million, with an annual value of about $264 million expected if the stock recovers to produce at MSY.

In the North Pacific, catch rates (and effort) in the U.S. troll fishery and the Japanese pole-and-line fishery have been declining concurrently with the decline in catch. The U.S. CPUE has declined about 50% since the 1960s. The CPUE for the Japanese fisheries has declined somewhat less. Previous assessments estimated MSY or Long-Term Potential Yield (LTPY) between 90,000 and 120,000 mt and estimated the stock was producing at or above LTPY in the 1970's. This high production, coupled with the addition of a drift gillnet fishery (for which catch and effort statistics are incomplete), leads to the current assessment that the stock may be overfished and may have suffered recent declines in recruitment. With the exception of the drift gillnet data, data for this stock are complete and generally available.

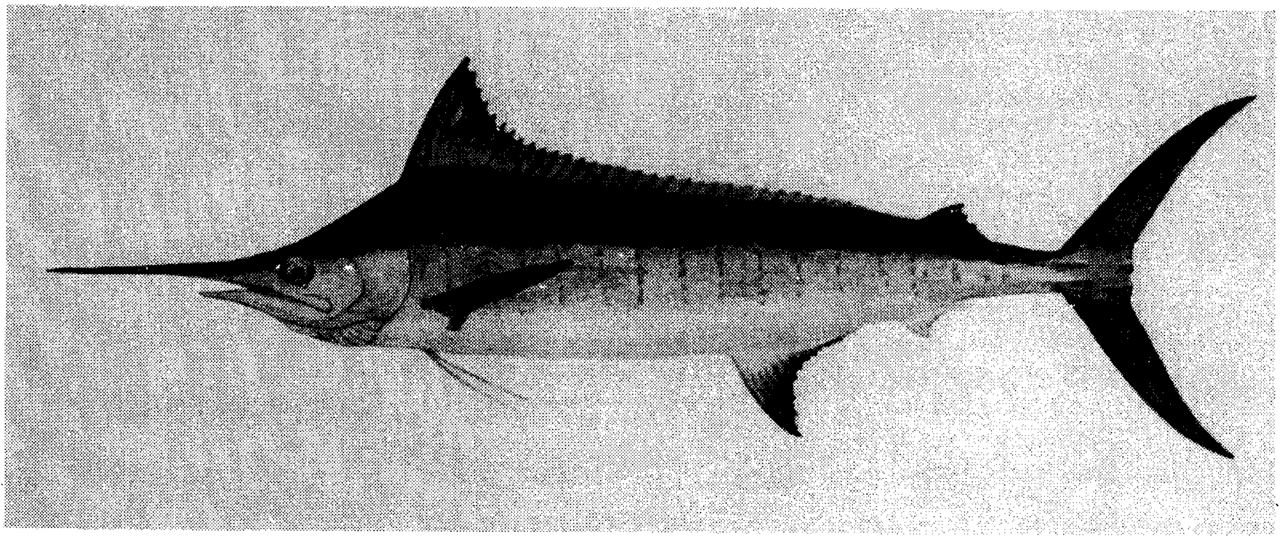
Table 4. Resource summary - North Pacific albacore.

Average catch (1988-90)	=	59,000 mt
Long-term potential catch (MSY)	=	90,000-120,000 mt
ABC (1990)	=	Unknown
Importance of recreational fishery	=	100-1,000 mt
Management	=	None
Status of exploitation	=	Probably overfished
Size at 50% recruitment	=	50 cm (females) 50 cm (males)
Size at 50% maturity	=	86 cm (females) 86 cm (males)
Assessment approach	=	Age, CPUE based
Fishing strategy ($F_{35\%}$)	=	None
F (1990)	=	Unknown

The North Pacific albacore stock is affected by high seas drift gillnets; however, the impact of the gillnet fishery on the status of the stocks is not clear since reliable data from these fisheries are not yet available.

In the North Pacific, the presumably overfished condition of the stock makes collection of data and evaluation of the effects of the drift gillnet fisheries an urgent issue. Presently there is no management regime for the North Pacific albacore fisheries. The creation of an international management forum for the stock is an outstanding issue, particularly if the fishing nations wish to encourage recovery of the stock. Currently, only an informal scientific forum, the North Pacific Albacore Workshop, is held biannually.

3. BLUE MARLIN



Courtesy of the Inter-American Tropical Tuna Commission (IATTC) from *Tuna and Billfish- Fish Without a Country.*

Blue marlin, *Makaira mazara*, is a tropical epipelagic species, distributed throughout the Pacific where surface waters are warmer than 24°C. Its swimming depth is shallower than striped marlin, *Tetrapturus audax*, based on relative efficiencies of deep and regular longline fishing gear. Sonic tracking indicates blue marlin spend most of their time at depths of <60 m. Apparent distribution changes seasonally, extending poleward to about 35°N and 35°S with spring warming, and then returning to between 10°N and 10°S during winter cooling. Spawning occurs throughout the year along the equator, extending poleward as far as 30°N and 30°S latitude in each hemisphere during summer. It has been assumed that there is a single Pacific-wide stock.

Blue marlin sometimes reach sizes greater than 900 kg, and most individuals over 130 kg are females, there being pronounced sexual dimorphism in this species. Pacific-wide, most longline-caught fish weigh between 70-170 kg. The smallest sexually mature males are about 35-44 kg and females begin maturing at about 47-61 kg. Growth has been estimated both from progression of length frequency modes and presumed annual external ridges on otoliths, with divergent results. For example, male fish measuring 175 cm eye-fork length (50 kg) are estimated to be 3.5 years old based on progression of modes and 8 years old based on otoliths. Eight-year-old females are larger, either 230 cm (100 kg, from progression of modes) or 300 cm (280 kg, from otoliths). The only estimates of natural mortality (0.2 for males and 0.5 for females) are based on growth models.

Table 5. Pacific blue marlin landings (mt) and domestic catch rate (mt/100 trips).

Category	YEAR											
	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Total Pacific	16,581	19,029	19,408	15,398	14,317	19,667	16,109	18,286	19,519	18,421	NA	NA
U.S. Western Pacific region	199	228	265	259	215	239	242	355	443	487	782	699
U.S. troll catch/100 trips	1.81	1.45	1.72	1.85	1.08	1.29	0.92	1.04	1.07	1.36	1.71	NA

Blue marlin are caught primarily as a bycatch of longline fisheries targeting tuna or other marlin species although blue marlin are valued as food fish in Japan and domestically in the central Pacific, where they have become an increasingly larger component of the domestic longline catch. Pacific-wide landings by commercial fisheries remained stable, between 15,000 and 20,000 mt from 1979 to 1988, with the bulk coming from Japanese longliners which landed 11,000-19,000 mt in 1979-85 and had peak landings in 1981. Combined longline landings by Taiwan and Korea decreased from about 2,800 mt in 1976 to about 400 mt in 1985. The Japanese drift gillnet fishery landed 200-1,200 mt in 1975-86 and had peak landings in 1981. The combined domestic longline and commercial troll fisheries in the Pacific increased their blue marlin landings from below 270 mt during 1979-85 to 700-800 mt in 1989-90, with most of the increase due to longliners increasing fishing effort and decreasing fishing depth (Figure 11). Most blue marlin landed by domestic fisheries are of adult size (>50 kg). Blue marlin are especially important to recreational fishermen throughout the Pacific, where this large marlin is a premium trophy fish.

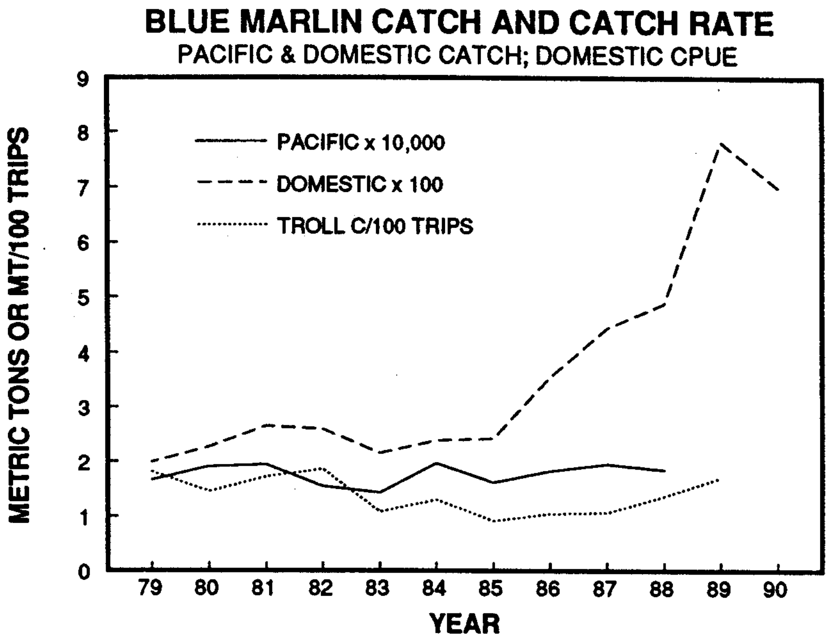


Figure 11.

Table 6. Resource summary - blue marlin.		
Average annual catch (1988-90)	=	17,795/383 mt (Pacific/domestic)
Long-term potential catch (MSY)	=	23,500 mt
Importance of recreational fishery	=	High
Management	=	FMP for the pelagic fisheries of the Western Pacific region
Status of exploitation	=	Overutilized
Assessment approach	=	GPM

The only index of abundance that is reasonably current is from the domestic commercial troll fishery which shows a decline in catch per trip from 1979 to 1985 and an increase from 1985 to 1989. Older Japanese data for the Pacific, standardized to account for changes in longline fishing depth, show a sustained decline in catch per unit effort (CPUE; metric tons per effective hooks per 5° square) from 1952 through 1977, followed by a small net increase from 1977 to 1985. Plots of yield versus fishing effort indicated a relatively flat production curve where increases in effort beyond the 1985 level would not lead to increased catches. Fitting a generalized production model to comparable (flat-topped) data suggested that the resource continued to be overutilized as in previous assessments and that additional increases in effort would result in further declines in catch. Although longline fishing effort by Japan has decreased since 1985, longline effort by other nations has increased. It is not known how current effort levels compare with earlier years.

Localized apparent abundance of blue marlin, at least for Hawaiian waters, is highly correlated with stock-wide abundance. Japanese longline CPUE in the central Pacific is correlated with troll and longline catch per trip in Hawaii, suggesting that the availability of blue marlin to local fishermen is strongly influenced by factors other than fishing pressure in local waters. Nevertheless, the catch rate of blue marlin by Hawaii longliners has been found to be significantly negatively correlated with Japanese longline effort in adjacent waters (1962-78 data).

No international management regime exists for blue marlin, nor is there any international agreement for exchanging data to monitor the fisheries. Domestically, a federal fishery management plan for the western Pacific includes blue marlin. The future status of the stock is unknown, because of lack of knowledge. If longline fishing effort increases or increasingly targets species living in the upper 100 m of the ocean in waters near the exclusive economic zone, there will likely be declines in blue marlin available to recreational fishermen. Management agencies may promote conservation of this resource for recreational fisheries. However, effective management will require the establishment of international agreements to exchange data, assess the stock, and perhaps reduce the longline bycatch of blue marlin.

4. EASTERN TROPICAL PACIFIC TUNAS

Yellowfin and skipjack tunas are generally tropical in distribution and are found from the equatorial side of the North Pacific Transition Zone (NPTZ) to the equatorial side of the South Pacific Subtropical Convergence Zone (STCZ). They are principally fished by purse seine in two distinct regions of the Pacific, the eastern Tropical Pacific (ETP) and the central-western Pacific (C-WP); also by longline Pacific-wide.

Yellowfin Tuna

The biology and population dynamics of ETP yellowfin have been extensively investigated and reported by the Inter-American Tropical Tuna Commission (IATTC). Yellowfin are upper trophic level predators, feeding opportunistically on fish and cephalopods. The majority of yellowfin females mature at 120 cm, although considerable variance exists. Males may mature as small as 50 cm. The sex ratio is approximately 1:1. Juvenile yellowfin may serve as prey for billfishes and sharks as well as other large predators. Small yellowfin tuna less than 85 cm are frequently found schooling with similar sized skipjack. Fish larger than 85 cm are frequently found in association with dolphins. Natural mortality for yellowfin is thought to be about 0.8 per year.

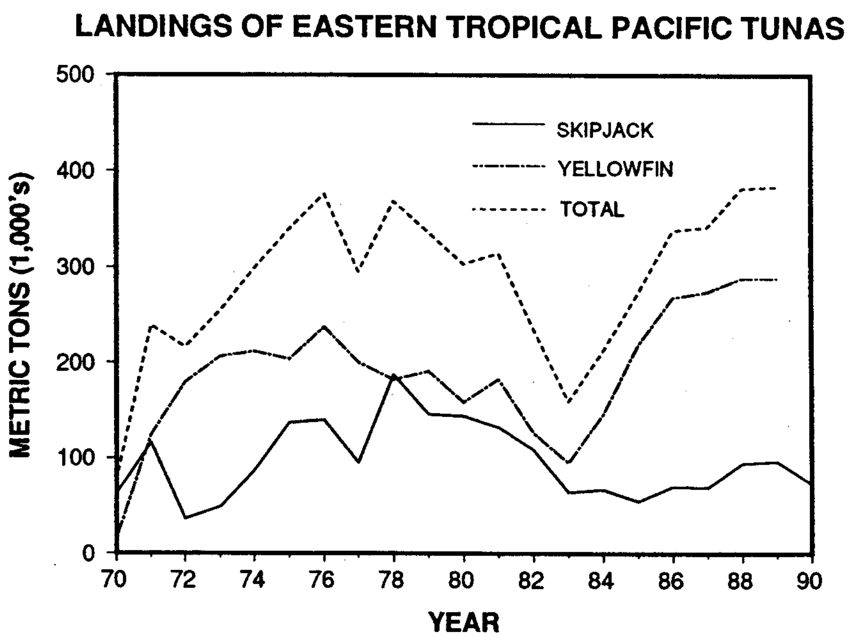


Figure 12.

Skipjack tuna biology and population dynamics have received less attention than those of yellowfin. Skipjack are distributed throughout tropical waters. Spawning occurs between October to March, generally toward the mid-Pacific. Prey is different for skipjack than that described for yellowfin, with crustaceans making up more than 50% of the diet. Skipjack grow rapidly. Rates of up to 28 cm per year for the first year, and half of this rate during the second year, are common. The maximum age of skipjack is approximately 5 years, although catches of fish older than 3 years are rare.

The ETP tropical tuna fisheries are generally concentrated between 20°N and 20°S latitude and have been extensively documented. The predominant fishing gear is the purse seine; other gears include longline and pole-and-line. The major fishery participant is Mexico; others include the U.S., Vanuatu, Venezuela, Panama, Spain, and Ecuador.

From 1970 to 1980 the fishery expanded and was dominated by the U.S. A series of events in the 1980s made fishing in the ETP less profitable, and considerable fishing effort left the ETP, leaving Mexico, with over 50 purse seiners, as the dominant fleet. The U.S. purse seine fleet operated about 35 purse seiners in the ETP in 1989, but the number decreased to about 10 in 1990 and 8 vessels in 1991, due to industry responses to public concern over the incidental kill of dolphins. The total number of U.S. and non-U.S. purse seiners operating in the ETP in 1990 was approximately 125.

Yellowfin catches have averaged over 265,000 mt during the last 5 years. Recent detailed assessments for yellowfin indicate that long term potential yield (LTPY) for the ETP is about 250,000 mt. This yield is greater than previously reported and is due to a period of high recruitment in the late 1980's and a shift in fishery operations raising yield-per-recruit. This species is fully utilized.

Skipjack catches averaged 80,000 mt in the last 5 years (Figure 12). The consensus is that the skipjack resource is underexploited, although its long-term potential yield is not known.

Based on a average ex-vessel price of $800 per metric ton (for both skipjack and yellowfin), the annual commercial value of the ETP yellowfin-skipjack resource is about $275 million.

In the ETP there is no resource-wide, unified fishery management scheme; each coastal nation-state regulates fishing within its EEZ. Until 1980, the IATTC regulated the fishery with a recommended quota management system. Since then, the fishing countries have not adopted the IATTC management recommendations, and fishing continues unregulated.

Table 7. Resource summary - ETP yellowfin.

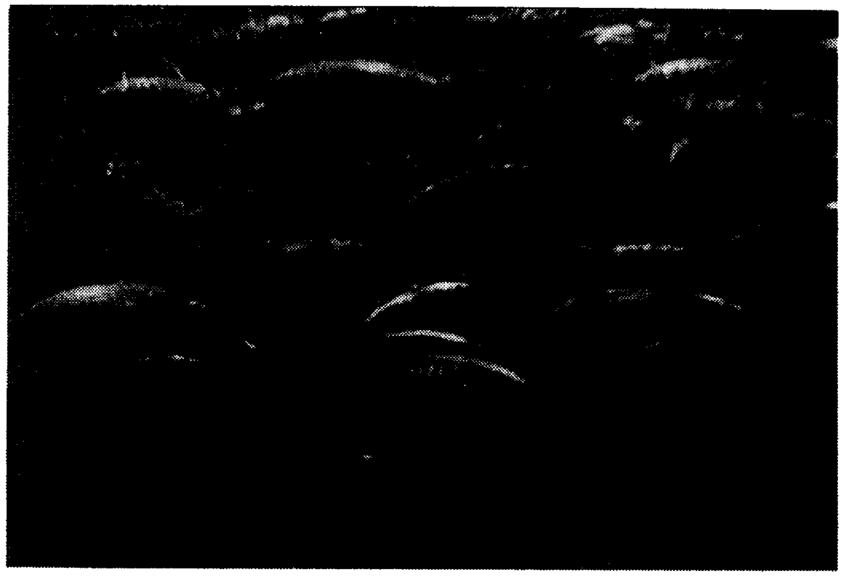
Average catch (1985-90)	=	265,000 mt
Long-term potential catch (MSY)	=	250,000 mt
ABC (1990)	=	Unknown
Importance of recreational fishery	=	1000 mt, seasonal, local
Management	=	Unregulated
Status of exploitation	=	Fully utilized
Size at 50% recruitment	=	35 cm (females) 35 cm (males)
Size at 50% maturity	=	90 cm (females) 90 cm (males)
Assessment approach	=	Age, CPUE based
Fishing strategy ($F_{35\%}$)	=	None
F (1990)	=	Unknown

Table 8. Resource summary - ETP skipjack.

Average catch (1985-90)	=	80,000 mt
Long-term potential catch (MSY)	=	Unknown
ABC (1990)	=	Unknown
Importance of recreational fishery	=	Minor, seasonal, local
Management	=	Unregulated
Status of exploitation	=	Underutilized
Size at 50% recruitment	=	35 cm (females) 35 cm (males)
Size at 50% maturity	=	40-50 cm (females) 40-50 cm (males)
Assessment approach	=	CPUE, tagging based
Fishing strategy ($F_{35\%}$)	=	None
F (1990)	=	Unknown

5. WESTERN TROPICAL PACIFIC TUNAS

The tropical tunas, yellowfin and skipjack, are principally fished by purse seine in two distinct regions of the Pacific, the eastern tropical Pacific (ETP) and the central-western Pacific (CWP) and by longline Pacific-wide. Skipjack and yellowfin tuna are distributed throughout the tropical and subtropical Pacific waters both north and south of the equator. In the CWP, they are fished between 20°N and 20°S latitude and west of 150°E longitude to southeast Asia.



Skipjack tuna

The stock structure of skipjack in the central and western Pacific is not well defined. Results of genetic studies indicate the gene pool is not panmictic Pacific-wide. However, blood-based genetic data suggest multiple population groups spawning across the Pacific which have considerable interchange; there are no isolated genetic stocks.

Tagging data show that although skipjack move extensive distances in all directions, most of the tag returns are within 200 miles. The maximum age of skipjack is approximately 5 years, although catches of fish older than 3 years are rare. Evidence from tagging data indicate that the population has an extremely high turnover rate, as high as 200% per year. Fishing mortality in the CWP in 1983 was as low as .05 of the turnover rate (at catch levels of 100,000 mt) and may currently be as low as .35 of the turnover rate (at a catch level of 750,000 mt).

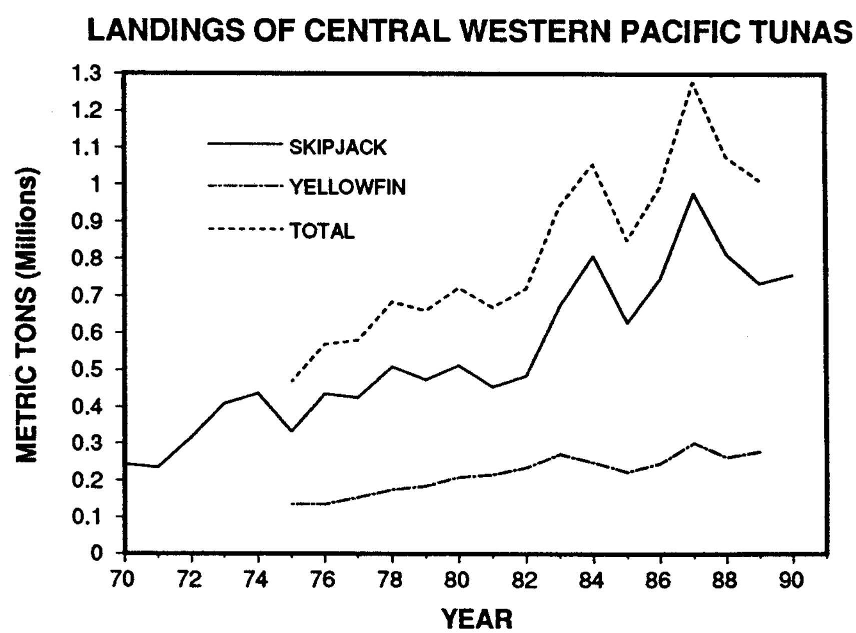


Figure 13.

Although yellowfin tuna have been studied extensively in the ETP, fewer investigations have been conducted in the CWP. Currently, an extensive tagging program is being conducted in the CWP by the South Pacific Commission to examine the dynamics of CWP yellowfin. Yellowfin are considered highly migratory from tagging evidence. Smaller sizes of yellowfin are typically surface schooling and often occur in mixed schools with skipjack.

The fishery in the CWP has many components. Fishing gears include purse seine, ringnet, handline, pole-and-line and longline. In the CWP the major fishery participants include the U. S., Japan, Korea, Taiwan and others, including island countries in the area. Virtually all the skipjack catch is taken by surface fisheries, primarily purse seine and pole-and-line, while about half the yellowfin catch is taken by longline and handline fisheries. Purse seines, dominated by the U.S. and Japan, take between 30% and 50% of the yellowfin catch. In 1989 the total number of purse seiners in the CWP was more than 120. In 1990 and 1991 approximately 50 U.S. seiners operated in the CWP.

Among the tunas, catches of skipjack are the highest. Skipjack and yellowfin tuna catch totals from the CWP for the period 1970 to 1990 are shown in Figure 13. Recent average yield (RAY) of CWP Pacific skipjack (Table 2) is 767,000 mt. The present consensus is that the Pacific skipjack resource is underexploited although the long-term potential yield (LTPY) is unknown. The recreational catches of skipjack are small.

Total yellowfin tuna catches from the CWP for the period 1970 to 1989 are shown in Figure 13. RAY for CWP is about 280,000 mt. LTPY for the CWP is unknown because there has not yet been a comprehensive analysis of catch rates of yellowfin tuna for the CWP purse seine fishery. However, catch rates are relatively steady and the incomplete analyses done to date suggest the fishery may be nearing full production.

Based on an average ex-vessel price of $800 per metric ton (for both skipjack and yellowfin) the annual commercial value of the CWP skipjack resource is about $550 million and for yellowfin, $225 million.

In the CWP, there is no overall resource management program although the Forum Fisheries Agency (FFA), an organization of 16 South Pacific island countries that has claimed jurisdiction over tuna resources in this region, has instituted licensing of fishing effort of distant-

Table 9. Resource summary - WP yellowfin tuna.

Average catch (1980-90)	=	249,000 mt
Long-term potential catch (MSY)	=	Unknown
ABC (1990)	=	>280,000 mt
Importance of recreational fishery	=	Small
Management	=	None
Status of exploitation	=	Unknown
Size at 50% recruitment	=	35 cm (females) 35 cm (males)
Size at 50% maturity	=	90 cm (females) 90 cm (males)
Assessment approach	=	CPUE based
Fishing strategy ($F_{35\%}$)	=	None
F (1990)	=	Unknown

Table 10. Resource summary - WP skipjack tuna.

Average catch (1980-90)	=	694,000 mt
Long-term potential catch (MSY)	=	>767,000 mt
ABC (1990)	=	>767,000 mt
Importance of recreational fishery	=	Small
Management	=	None
Status of exploitation	=	Underutilized
Size at 50% recruitment	=	35 cm (females) 35 cm (males)
Size at 50% maturity	=	40-50 cm (females) 40-50 cm (males)
Assessment approach	=	Tagging based
Fishing strategy ($F_{35\%}$)	=	None
F (1990)	=	Unknown

water fishing fleets. The U.S. fleet is currently limited to 50 purse seiners, under the terms of the South Pacific Regional Tuna Treaty.

The primary issue facing tropical tuna assessment and management in the Pacific is the lack of consensus on a plan for gathering statistics and reporting and on structuring a fishery management/resource conservation organization that includes all stakeholders. This lack of data precludes definitive assessments. The issues of resolving stock structure as well as securing basic biological data need to be addressed.

6. STRIPED MARLIN

Striped marlin, *Tetrapturus audax*, is an epipelagic fish occurring in waters from about 45°S to about 45°N latitude in the western Pacific and from about 30°S to about 35°N latitude in the eastern Pacific. Individuals may reach a maximum size of about 290 cm eye-fork length (260 kg), but sizes differ with area. The largest fish are found in the southwestern Pacific, with longline-caught fish ranging from 40-80 kg. Size at first maturity is about 150 cm eye-fork length (30 kg). In the western Pacific, striped marlin are found mostly in subtropical waters. Both adult abundance and spawning are concentrated in latitudinal bands between 10° and 30° north and south of the equator and west of 130°W longitude. Spawning occurs primarily during the early summer in each hemisphere. Striped marlin is the dominant marlin in the central north Pacific and in the eastern Pacific where there is no equatorial gap in abundance. For stock assessment purposes, it has sometimes been assumed that there are separate northern and southern stocks. Age and growth rates have been only poorly quantified, based on progression of length-frequency modes, and the only estimates of natural mortality (0.5-1.3) have been based on such growth rate estimates.

Most striped marlin are caught by longline fisheries targeting tuna. However, striped marlin are commercially valuable, being a major component of landings by the U.S. longline fishery in the Pacific (Hawaii) where this species is among the fish most affordable to domestic consumers. Also, striped marlin is the most desirable billfish for sashimi in Japan. Drift gillnet fisheries operat-

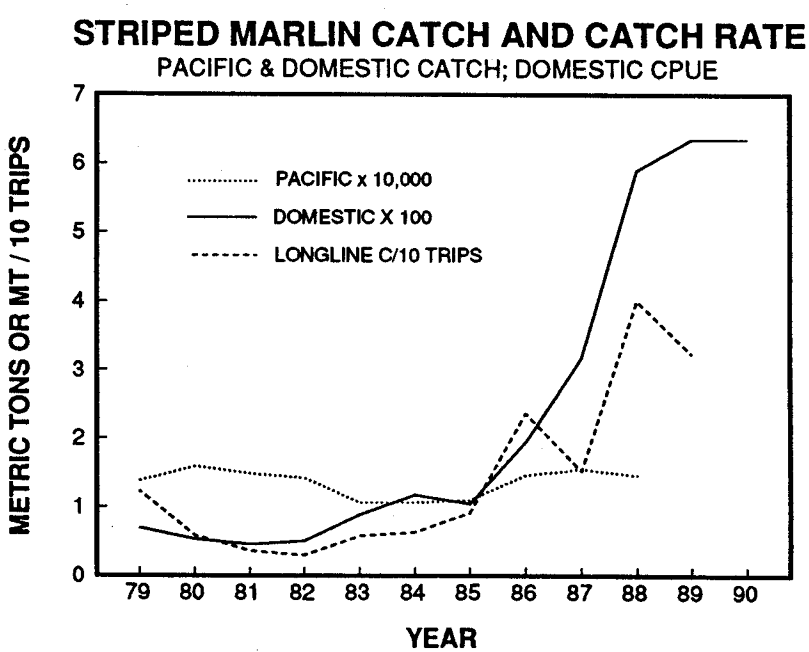


Figure 14.

Table 11. Pacific striped marlin landings (mt) and catch rate (mt/10 trips).

Category	YEAR											
	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Total Pacific	13,862	15,870	14,857	14,173	10,683	10,690	11,052	14,700	15,495	14,659	NA	NA
U.S. Western Pacific region	70	53	46	51	89	118	105	195	318	590	635	635
U.S. longline catch/10 trips	1.23	0.59	0.36	0.30	0.58	0.64	0.92	2.37	1.53	4.01	3.24	NA

ing in the northwestern Pacific catch substantial quantities of striped marlin but less than during the 1970s because of a shift in targeting towards albacore, *Thunnus alalunga*. The coastal harpoon fisheries in Japan, Taiwan, and California no longer land any striped marlin. Recreational fishing for striped marlin is important in the eastern Pacific off California and Mexico, but elsewhere in the Pacific, anglers are more interested in the larger blue marlin, *Makaira mazara*, or black marlin, *M. indica*.

Pacific-wide landings of striped marlin have been stable, in the range of 10,000-15,000 mt from the early 1970s through 1988, with no particular trend in recent years (Figure 14). Previous landings were higher, the decline probably reflecting a change in longline fishing towards using deeper gear to target bigeye tuna, *Thunnus obesus*. The bulk of the Pacific-wide landings were by Japanese longliners, but Japanese gillnet landings amounted to about 1,800-6,500 mt in 1975-86, making this the largest North Pacific fishery for striped marlin during this period. Taiwanese and Korean longliners landed relatively small amounts of striped marlin from 1975 to 1985 (100-1,000 mt/year combined) although these fisheries have increased operations since 1985 while the Japanese longline fishery has decreased. The U.S. longline fishery based in Hawaii increased its striped marlin landings from below 200 mt during 1979-85 to around 600 mt during 1988-90. This fishery tends to harvest fish smaller than adult size (50% of the catch weighs less than 30 kg). The domestic fishery underwent a fourfold expansion from 37 vessels in 1983 to about 150 in 1990. Nevertheless, domestic landings still amount to <5% of the Pacific-wide total, and landings by other U.S. fisheries in the Pacific are small in comparison.

The only reasonably current index of abundance from the domestic longline fishery showed a threefold increase in landings per trip from 1985 to 1989. This index is badly confounded by an increase in the amount of fishing gear deployed per trip, a decrease in fishing depth, and other changes. However, there is no evidence of any major trend in stock-wide abundance based on older data. The most recent stock assessments using Japan's longline data through 1985, corrected for changes in fishing depth, showed wide variations in catch per unit effort (CPUE) with no apparent trend or impact of fishing effort on CPUE in the northern stock. A weak relationship between fishing effort and CPUE was found for the southern stock, suggesting that it was optimally exploited at the 1985 level of fishing effort. An analysis assuming a single Pacific-wide stock using data through 1980 suggested that the combined stock could be further exploited. Although an up-to-date definitive stock assessment is lacking, no evidence suggests that the stocks are fully utilized. On a local scale, longline fishing pressure may be intense enough to cause temporary declines in the availability of striped marlin to nearby fisheries. When a Japanese longline fishery targeting striped marlin within Mexico's 200-mile exclusive economic zone (EEZ) was excluded by new regulations in 1976, trolling CPUE by recreational anglers increased rapidly and then began to decline again when joint-venture longline fishing resumed in the area. Similarly, striped marlin catch rates by Hawaii longliners (1962-78 data) were found to be negatively correlated with Japanese longline effort in adjacent waters.

No international management regime exists for striped marlin, nor is there any international agreement for exchanging data to monitor the fisheries. State and federal agencies in the United States exercise a few management options. For example, California prohibits the sale of striped marlin, so the domestic harpoon and driftnet fisheries no longer target the species. A preliminary fishery management plan (FMP) and subsequent versions of the FMP for pelagics by the Western Pacific Regional Management Council (WPRFMC) required foreign longliners fishing in western Pacific EEZs to enter port and take on observers. This regulation virtually stopped all foreign fishing in the U.S. EEZ in 1980. Most recently the WPRFMC ruled that domestic longline vessels must submit logbooks and has obtained an emergency moratorium freezing the number of vessels in the Hawaii domestic longline fishery. If the moratorium is extended for 3 years, as intended, this will slow further in-

Table 12. Resource summary- striped marlin.

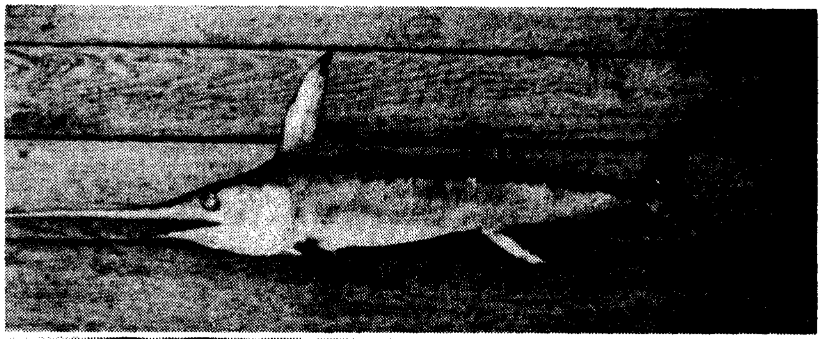
Average catch (1980-90)	=	13,575/258 mt (Pacific/domestic)
Long-term potential catch (MSY)	=	Unestimated
Importance of recreational fishery	=	Low in W. Pacific; high off West Coast
Management	=	FMP for the pelagic fisheries of the Western Pacific region
Status of exploitation	=	Probably underutilized
Assessment approach	=	GPM attempted

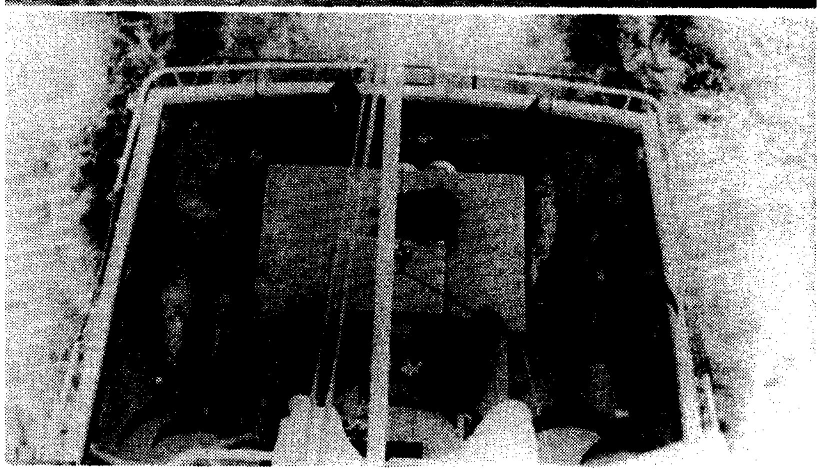
creases in the domestic landings of striped marlin, and logbook data will permit the calculation of meaningful indices of abundance for the first time since foreign longline data became unavailable after 1980.

The lack of proper fisheries statistics and stock assessments makes it impossible to draw conclusions regarding the status of striped marlin stocks. The conservative exploitation of this resource will require the establishment of international agreements to exchange data and manage the fisheries.

7. SWORDFISH

The swordfish, *Xiphias gladius*, is a large pelagic fish (to approximately 500 kg) distributed throughout the temperate, subtropical, and tropical waters of the Pacific Ocean. It is found in oceanic as well as coastal waters. Spawning occurs in subtropical and tropical waters in the spring, with progressively older and larger fish found in the more poleward extremes of the distribution. There is evidence of sexually dimorphic growth, but growth is not well-documented, particularly in the Pacific. Virtually nothing is known about the movement of swordfish in the Pacific, but predominantly north-south movement is expected, based on the Atlantic model.





The domestic fishery along the eastern border of the Pacific has evolved from what was predominantly a harpoon fishery to what is now almost exclusively a driftnet fishery. The average dressed size of the California landings has been around 1.5 m. In Hawaii, the night longline fishery for swordfish started in 1989, with the introduction of chemical light sticks from the Atlantic fishery. Fish from about 10 to 400 kg are landed in this fishery. Swordfish landings in other U.S. Pacific island fisheries are virtually nonexistent. In other areas of the Pacific, oceanic longline fishing has been conducted primarily by Japan in temperate waters of the North Pacific; coastal fisheries occur off Japan, Taiwan, Mexico, Chile, and Australia.

Total Pacific landings since 1980 have averaged under 20,000 mt per year, but the trend has been upward in recent years (Figure 15). The West Coast drift gillnet fishery expanded about 890% in 1980-85, reaching 2,300 mt in 1985. Subsequently the fishery declined with the landings equaling 1,300 mt in 1989. The incidental take of swordfish in Hawaii fluctuated between 16 and 40 mt, but jumped to 1,600 mt in the second year of the directed fishery.

The most recent stock assessment in 1989 using data only through 1980 indicated that the resource on a Pacific-wide basis may be somewhat underutilized. However, the assessment should be considered provisional for the following reason. Data are unavailable to standardize the fishing effort statistics in response to known historical changes in longline fishing strategies. The fishery historically started as what was predominantly a night longline fishery and then changed to a day fishery. Recently, deep longline gear has come into use. Comparing Pacific catches with the harvests obtained in the Atlantic would suggest that the Pacific stock is substantially underutilized, although it should be remembered that the Atlantic stock is now regarded as overutilized, if not overfished.

Current management mechanisms by the State of California and the federal government in the central and western Pacific are probably sufficient to manage the fisheries in

Table 13. Pacific swordfish landings (mt).

Category	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Total Pacific	19,179	16,616	18,937	18,649	18,770	17,085	19,426	20,558	22,569	25,624	NA	NA
U.S. Western Pacific Region	17	24	17	36	40	28	16	23	22	39	298	1645
U.S. West Coast	266	543	518	767	1213	1993	2357	1745	1243	1127	1298	NA

their respective jurisdictions. However, with the swordfish stock boundary encompassing the north, if not the entire Pacific, these management mechanisms are not capable of managing the resource. No international management mechanisms exist for swordfish in the Pacific.

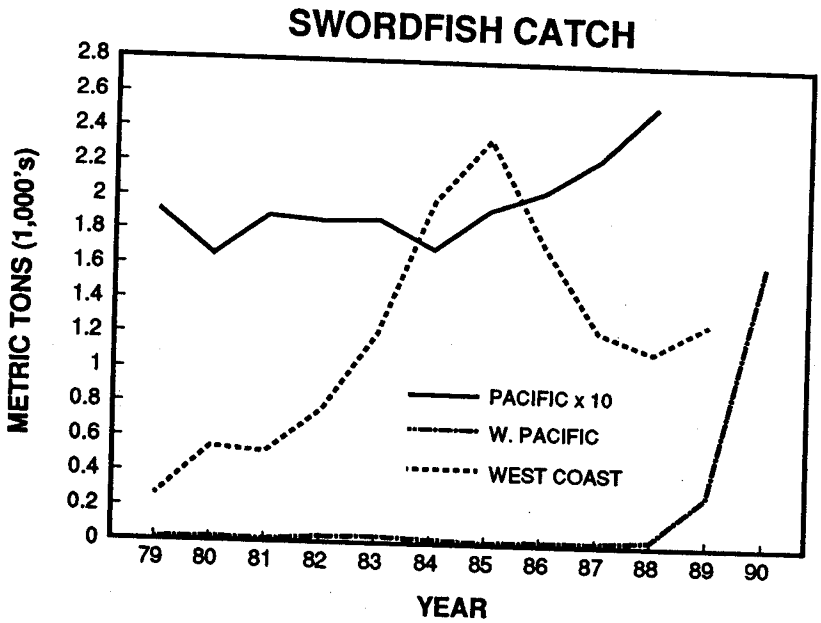
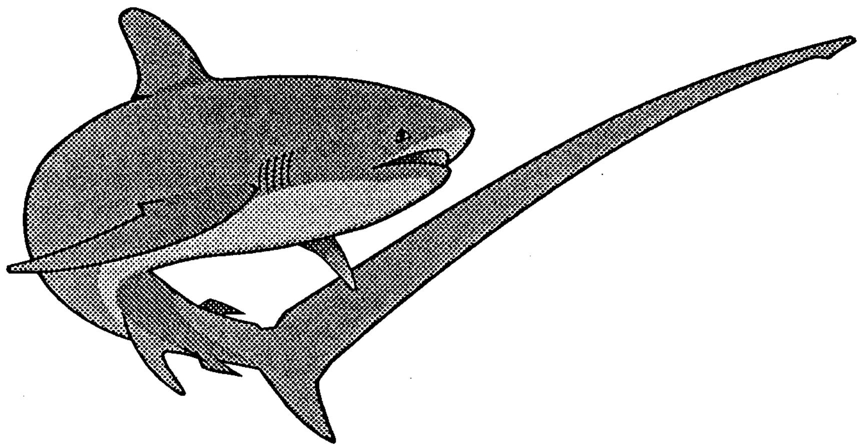


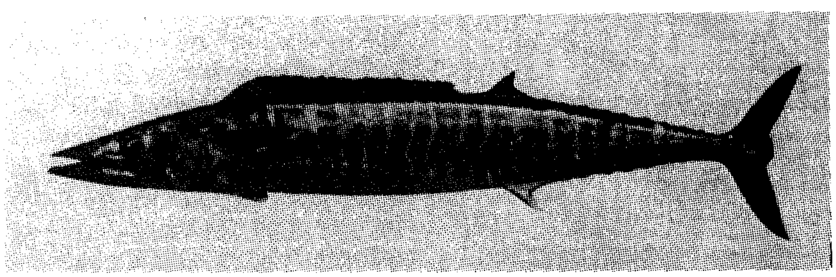
Figure 15.

With the demonstrated fishing power of the U.S. longline swordfish fleet and its ability to target resource concentrations in the Atlantic which has resulted in rapid declines in local abundance (particularly of large, commercially desirable individuals), the continuing high market demand for swordfish, and the subsequent decline in the Atlantic fishery, considerable concern exists regarding the consequences of unregulated expansion of Hawaii's fishery. However, with the initiation of a moratorium on the entry of new longline vessels into Hawaii's fishery in 1991 and the curtailment of growth of the California fishery, the status of the resource within the U.S. Pacific exclusive economic zone is not likely to change substantially in the near future. The impact of the growth of other coastal fisheries on the U.S. fisheries is not known.

Table 14. Resource summary - swordfish.		
Average catch (1980-90)	=	19,804/1,363 mt (Pacific/domestic)
Long-term potential catch (MSY)	=	19,000 mt (provisional)
Importance of recreational fishery	=	Very minimal
Management	=	FMP for the pelagic fisheries of the Western Pacific region
Status of exploitation	=	Probably underutilized
Assessment approach	=	GPM

8. OTHER LARGE PELAGICS





Top left- thresher shark, bottom left- wahoo, and above- mahimahi.

Included in this unit are a number of bony and cartilaginous pelagic fishes. The teleosts include the dolphin or mahimahi, *Coryphaena hippurus*; wahoo, *Acanthocybium solandri*; shortbill spearfish, *Tetrapturus angustirostris*; sailfish, *Istiophorus platypterus*; and black marlin, *Makaira indica*. Sharks include oceanic members of the requiem, thresher, and mackerel shark families.

The bony fish members of this group inhabit epipelagic waters of the tropics and subtropics in the Central and Western Pacific. Hence, their occurrence is not common as far north as California in the eastern Pacific. Directed domestic troll fisheries exist throughout the western Pacific region for mahimahi and wahoo. The largest domestic harvest occurs in Hawaii, although it is minor compared to the harvest of other pelagic species. In contrast, the Guam troll fishery lands more mahimahi and wahoo than other pelagic species because of a local lack of preference for tunas. Significantly larger foreign fisheries for mahimahi occur off central America, Taiwan, and Japan. Other fishing gear taking these bony fishes incidentally include tuna longline and pole-and-line in the U.S. exclusive economic zone (EEZ) and tuna purse seine, other types of surround nets, and driftnet outside the EEZ. Shortbill spearfish is a common component of the Hawaii longline catch, but the major incidental take of this species is to the north in foreign longline fisheries. Sailfish and black marlin are uncommon in all domestic fisheries in the Pacific, with the major foreign catches occurring in the tropical or subtropical continental margins of the Pacific. Recreational landings of these bony fishes in Hawaii are thought to be substantial, but current estimates are not available. A State of Hawaii-operated recreational survey, which was designed with federal funding, is now (1991) in the pilot testing stage.

Mahimahi landings make up the largest portion of the landings of this group of miscellaneous pelagics.

Total (foreign and domestic) landings are considerably larger than domestic landings. Pacific landings have been variable since 1979 with the two largest values recorded in 1987 and 1988 (Figure 16). Hawaii landings have been increasing since 1979, particularly after 1984.

The world record for the largest mahimahi is 39.5 kg (87 lb). During 1988-89, the largest fish landed in Hawaii was 145.7 cm fork length (FL) and weighed 29.8 kg (65.5 lb). Generally, recent landings in Hawaii consist of fish 2.3-22.7 kg (5-50 lb). Males frequently weigh twice that of females for a given length after sexual maturity. Ovarian tissue examinations revealed that the smallest mahimahi known to have spawned in the wild was 86.1 cm FL (ca. 5 kg) or about 7-8 months old. Spawning occurs throughout the year in tropical waters and in a long extended season of about 9 months in the subtropics. Mahimahi is a batch spawner and has been observed to spawn every other day in captivity. The spawning frequency of wild fish has not yet been determined. Spawning occurs over the continental shelf and around islands in mid-ocean. Growth is rapid, and in its first year a male can attain 20 kg and a female 14 kg.

The major domestic shark fishery occurs off the west coast of the continental United States; only minor catches occur in the western Pacific region. The West Coast fishery, developed in the mid-1970s, harvests thresher, Pacific angel, soupfin, and shortbill mako, among other species. The fishery now is primarily off California although fisheries off Washington and Oregon occurred in 1983, 1984, and sporadically in other years. Drift gillnet is the primary commercial gear, but recreational fishing is also important in the area. Sportfishing for shark is virtually nonexistent in the Western Pacific region.

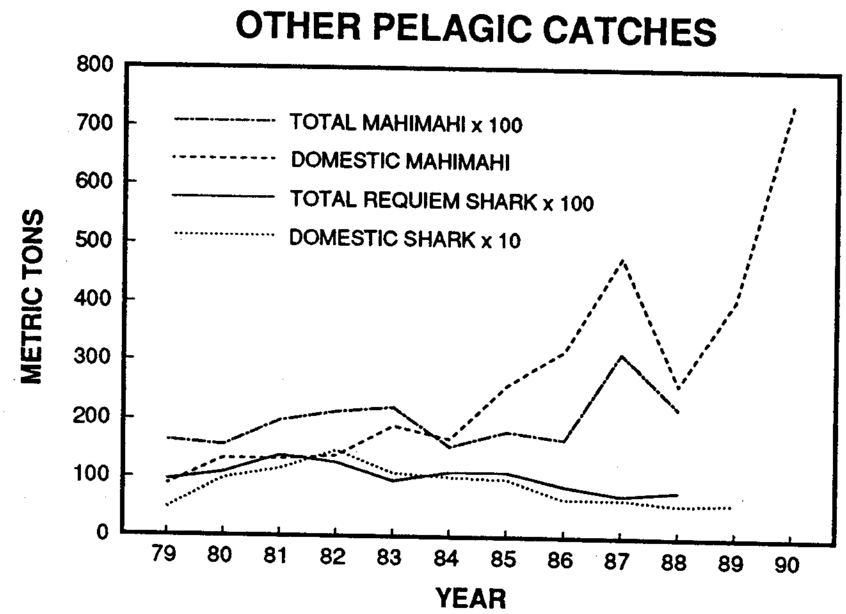


Figure 16.

Harvest levels of shark in the Pacific are not well documented, but even so, reported foreign landings of requiem sharks are considerably greater than the domestic harvest of all sharks (Figure 16). Landings may be declining slightly. The U.S. shark harvest (primarily California landings) reached a high in 1982 and has since declined by 60% (Figure 16).

Based on extensive tuna longline and surface trolling data, wahoo appear to prefer shallow depths and are more abundant close to land than in the open ocean. Wahoo are not very abundant in the Central Pacific, but they are highly valued as are other seerfish in other parts of the world. The maximum size is 210 cm FL or 83 kg (183+ lb); Hawaii fish range between 71 and 174 cm FL. Spawning may occur throughout the year near the equator, but it is limited to the summer in the subtropics. Wahoo begin spawning at about 100 cm FL.

The shortbill spearfish occurs in temperate and tropical waters of the Pacific. Longline catch data indicate that this species occurs roughly between 40°N and 35°S latitude in the Pacific. Although this species does not appear to be generally abundant, longline catch rates increase in the Northwest Pacific between 15°N and 30°N latitude from November through February. Shortbill spearfish are known to grow to 52 kg (114 lb). Spawning occurs throughout the year with a peak during the summer.

The pelagic requiem sharks (Carcharhinidae) are the silky shark, *Carcharhinus falciformis*; oceanic whitetip shark, *C. longimanus*; dusky shark, *C. obscurus*; and blue shark, *Prionace glauca*. These species are tropical, except for blue sharks which are also found in temperate waters. Most requiem sharks have up to 15 pups in a litter, which is relatively small compared to blue sharks which have up to 135 in a litter. These sharks are incidentally caught on tuna or swordfish longlines in the central Pacific and are also targeted by the U.S. west coast pelagic driftnet fisheries.

Thresher sharks consist of the pelagic thresher, *Alopias pelagicus*; bigeye thresher, *A. superciliosus*; and thresher shark, *A. vulpinus*. The latter is the most commercially sought. These species have two to four in a litter, usually two. They are a major component of the west coast driftnet fishery, while being taken only occasionally by swordfish and tuna longline gear in the central Pacific.

The mackerel sharks (Lamnidae) are the shortfin mako, *Isurus oxyrinchus*, and the longfin mako, *I. paucus*. These species are generally tropical with only juveniles entering the west coast driftnet fishery. The shortfin mako has 4 to 16 pups in a litter, whereas the longfin mako has two. The shortfin mako is prized on the Pacific West Coast as a game fish where it is caught by trolling. Makos are taken by tuna and swordfish longline gear in the central Pacific.

Table 15. Resource summary- other large pelagics.

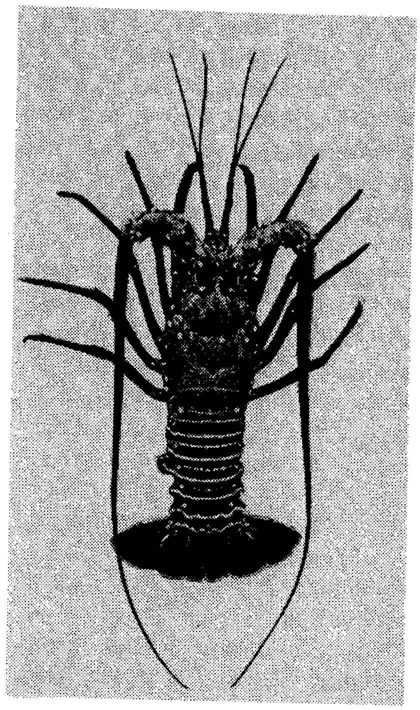
Average catch (1980-90)	=	43,270/1,347 mt (Pacific/domestic)
Long-term potential catch (MSY)	=	Unknown
Importance of recreational fishery	=	Important for mahimahi, wahoo, and shortbill spearfish in western Pacific; important for sharks on the West Coast
Management	=	FMP for the pelagic fisheries of the Western Pacific region; Calif., Oreg., and Wash. state regulations
Status of exploitation	=	Not well known
Assessment approach	=	GPM

Little is known about the stock composition or population dynamics of any of these species (Table 15). Because of the low fecundity of the sharks, those resources that have been examined have shown little resiliency to harvest. Because of its high fecundity, early maturation, and multiple batch spawning, mahimahi is probably reasonably resilient to harvest, but considerable fluctuation in harvest level is likely because of the few number of year classes in most fisheries.

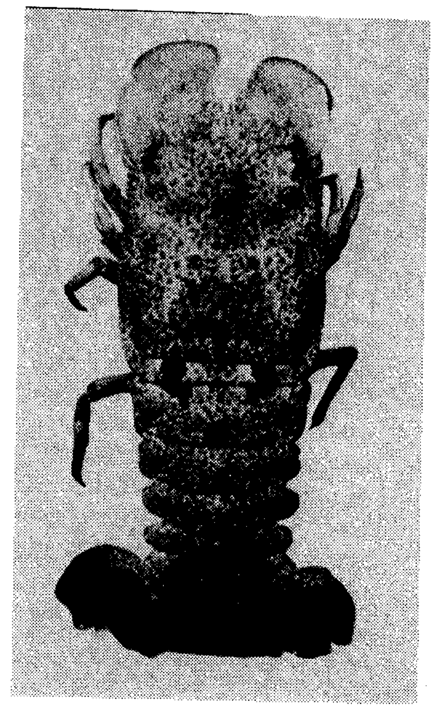
9. LOBSTERS

The commercial fishery for lobster in the Hawaiian Archipelago primarily exploits two species, spiny lobster, *Panulirus marginatus,* and slipper lobster, *Scyllarides squammosus.* Spiny lobster spawn throughout the year and have the greatest abundance of females with eggs in summer and fall. Slipper lobster spawn in spring and early summer. Both species have pelagic larvae. Spiny lobster larvae may spend 1 year in the pelagic stage, whereas slipper lobster larvae may have only a 3-month pelagic stage. Tagging and length-frequency studies estimate that, after settling from the pelagic stage, both species reach sexual maturity in slightly less than 3 years. Slipper and spiny lobsters also reach minimum legal harvest size at slightly more than 3 years from settlement. The lobsters are found from the surf zone to a depth of 200 m, but most commercial trapping occurs at depths of 20-80 m. Because of the very low catch rates of both species in the main Hawaiian Islands, commercial trapping for these species occurs almost exclusively in the Northwestern Hawaiian Islands.

Commercial trapping for slipper and spiny lobsters began in the late 1970s in the Northwestern Hawaiian Islands. In the early 1980s, landings (Figure 17) were almost exclusively spiny lobster, but during 1984-87, about one-half the catches were slipper lobster because of a change in gear and targeting by fishermen. Since 1988, the landings have been composed of about 80% spiny lobster, apparently as a result of higher prices for spiny lobster than for slipper lobster, and poor catch rates for slipper lobster. In recent years, about 1 million lobsters, valued at about $6



Spiny lobster.



Slipper lobster.

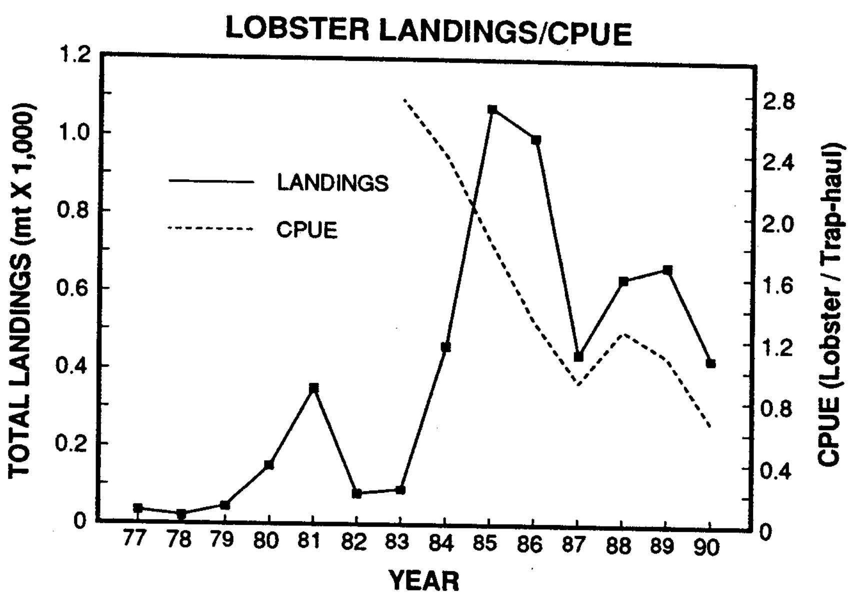


Figure 17. Landings and CPUE.

million ex-vessel, have been landed annually. Over 75% of the landings have come from three banks--Maro Reef, Gardner Pinnacles, and Necker Island. The composition of the fleet has ranged from 9 to 14 vessels (50 to 80 feet long), and these average 3 trips per vessel. The vessels typically fish about 800 traps per day and remain at sea almost 2 months per trip.

The fishery is managed under a fishery management plan (FMP) which went into effect in 1983. The FMP has established minimum sizes for slipper and spiny lobsters and prohibits the harvest of egg-bearing females. After research by the Honolulu Laboratory demonstrated that escape vents would reduce the sublegal catches and thus the mortality due to handling and release, the FMP was amended to require that traps have escape vents. Mandatory logbooks provide daily legal catch and trapping effort. Overfishing is defined to occur when the spawning stock biomass per recruit is less than 20% of the spawning stock biomass per recruit in the absence of fishing. An amendment to the FMP is under review to make it a limited entry fishery with 15 vessels licensed to harvest an annual catch quota during a season which begins 1 July and ends when the quota has been harvested or 31 December, whichever occurs first. The licenses are freely marketable. The catch rates from the Honolulu Laboratory's summer lobster sampling cruise will be one of the factors used to set the catch quota.

Commercial catch and effort data are collected from the logbooks. Commercial landings and catch per-unit effort (CPUE) show the trend typical of a developing fishery, with a period of rapid increase in landings and decline in CPUE (1983-86) as the stock is fished down, followed by a period of more stable landings and CPUE (1987-90) (Table 16). For stock assessment, scientists have used a dynamic Fox production model and a simple size-structured (Schnute) model. The former has been used to estimate long-term potential catch, and the latter model uses monthly commercial catch and effort data to estimate average recruitment, natural mortality, and catchability and, hence, the relative spawning stock biomass per recruit. The maximum sustainable yield (MSY) is estimated at 625 mt (1 million lobsters) with an effort of 1 million trap-hauls. With fishing effort of 1 million trap-hauls, the spawning stock biomass per recruit is 40% of the level in the absence of fishing. In 1990, effort was 1.2 million trap-hauls, 20% above the effort level which is estimated to achieve MSY. However, the relatively low catch in 1990 is believed to be the result of poor recruitment to the fishery, due to high advection and hence loss of larvae in 1986. Research is beginning to investigate the relationship among the abundance of lobster larvae, a measure of annual current flow along the Hawaiian Ridge, and subsequent recruitment to the fishery.

Table 16. Landings (mt) and catch per unit effort (CPUE: number of lobsters per trap) for the lobster fishery in the Northwestern Hawaiian Islands, 1977-90.

YEAR	LANDINGS	CPUE
1977	33	--
1978	20	--
1979	45	--
1980	150	--
1981	350	--
1982	80	--
1983	90	2.75
1984	462	2.38
1985	1077	1.83
1986	1000	1.31
1987	441	0.92
1988	638	1.26
1989	669	1.09
1990	431	0.66

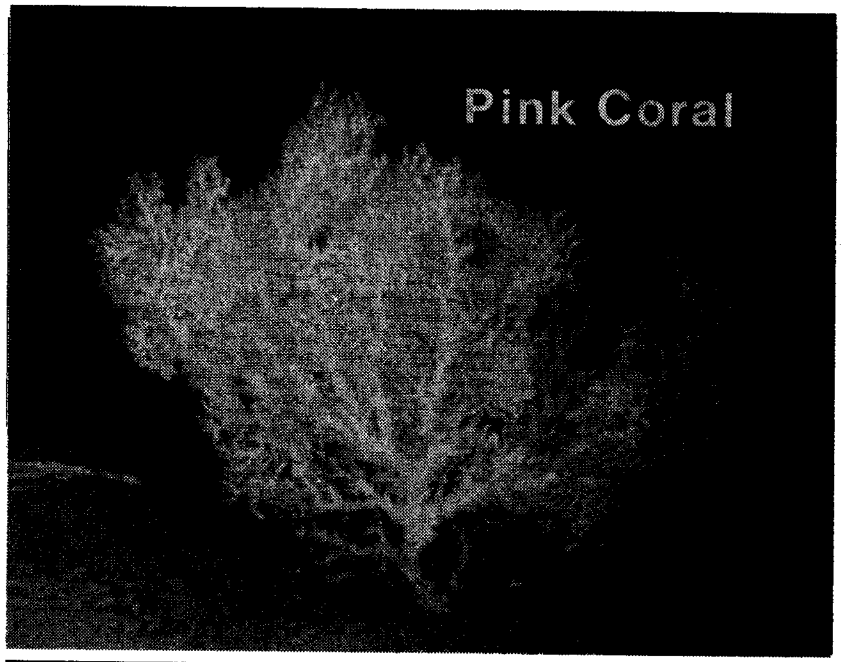
Table 17. Resource summary - Hawaiian lobster fishery.

Average catch (1980-1990)	=	490 tons
Long-term potential catch (MSY)	=	625 tons
ABC (1990)	=	200 tons
Importance of recreational fishery	=	None
Management	=	FMP
Status of exploitation	=	Fully exploited
Minimum legal size	=	5.0 cm tail width (spiny) 5.6 cm tail width (slipper)
Size at 50% maturity	=	4.4 cm tail width (spiny) 5.1 cm tail width (slipper)
Assessment approach	=	Size-based CPUE time series model and dynamic production model
F (1990)	=	1.1

10. PRECIOUS CORALS

Deepwater, ahermatypic (non-reef-building), gorgonian and zoanthid corals have supported episodic "boom-and-bust" fisheries world-wide for centuries. Only recently did a short-lived fishery for several genera of gold and bamboo corals, and for pink corals of the genus *Corallium* (chiefly *C. secundum*), exist in Hawaiian waters. This fishery occurred during 1974-79 off Makapu'u Point, Oahu, Hawaii. Since that time, the prohibitive costs of fishing this and other difficult-to-harvest deep-water coral resources have stifled exploitation in Hawaiian waters and the surrounding U.S. exclusive economic zone (EEZ) elsewhere in the South Pacific. With the exception of one aborted attempt at Hancock Seamount in the Hawaiian EEZ in 1988, legal domestic harvesting of precious coral within the EEZ has been nonexistent for the past 12 years (Figure 18). Recreational fisheries are nonexistent.

Precious coral resources within the EEZ are currently managed by the Western Pacific Regional Fishery Management Council's Precious Coral Fishery Management Plan (FMP), established in September 1983. Fishing is by regular permit or "experimental fishing permit" (EFP) only, with logbooks required of permittees. The FMP regulates precious coral fisheries within the EEZ seaward of the main Hawaiian Islands and Northwestern Hawaiian Islands, Guam, American Samoa, and the U.S. Pacific island possessions of Johnston Atoll, Kingman Reef, and Palmyra, Wake, Jarvis, Howland, and Baker Islands. Potential harvesting is regulated by quotas that are site-specific, with four types of sites or "beds" recognized (Table 18).



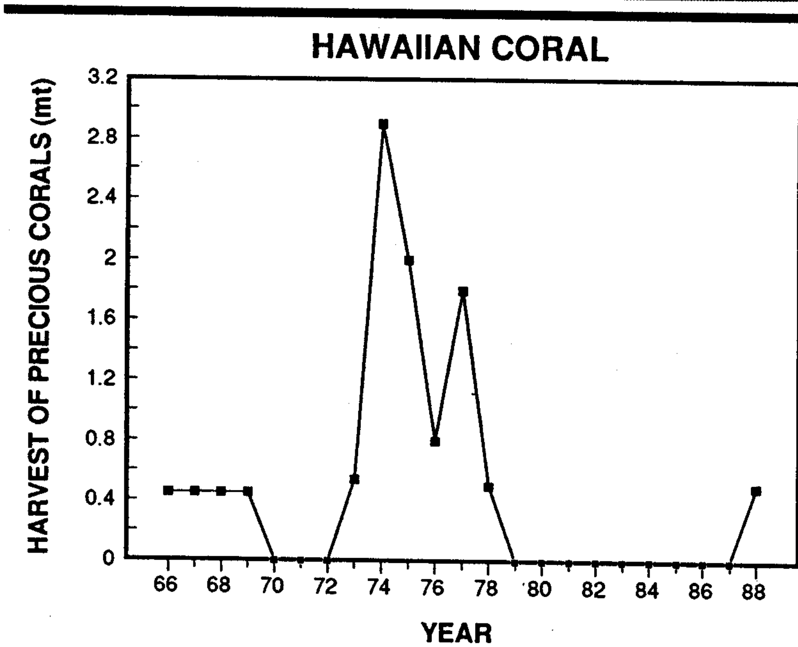


Figure 18. Total yield per year for various beds and types of precious corals. (Only the Makapu'u bed was harvested during 1966-79, as follows: 1966-69, pink coral only, 1.8 mt/3 year; 1970-72, no harvesting; 1973, pink coral only; 1974: 75% pink, 25% gold; 1975, 69% pink, 31% gold; 1976, 52% pink, 48% gold; 1977, 81% pink, 19% gold; 1978, 90% pink, 10% gold; 1979-87, no harvesting; 1988, Hancock Seamount, NW Hawaiian Islands' exclusive economic zone, 450 kg, pink coral. Source: FMP for the precious coral fisheries of the Western Pacific Region.)

Management guidelines are based solely on estimates of MSY for pink, gold, and bamboo corals at the lone "established" (Makapu'u) bed. Quotas for conditional beds are extrapolations based on area of the bed relative to size (3.5 km^2) of the Makapu'u bed. Estimated vital rates at the Makapu'u bed may differ at other beds of precious corals. Nonetheless, it is likely that because of the longevity (80 years), slow growth (0.9 cm/year), and low natural mortality rate ($M = 0.06$) of pink coral at Makapu'u, the long-term potential yield (LTPY or maximum sustainable yield (MSY)) is generally low for all species/types and beds of precious corals. The FMP has equated current potential yield (CPY) with MSY expressed on an annual basis (Table 19). At present even the Makapu'u bed off Oahu is unexploited; hence, all recent average yield (RAY) is zero.

Several amendments to the FMP have been developed in recent years. In March 1988, amendment 1 to the FMP added several conservative items: All U.S. island possessions were defined as a combined, single exploratory permit area with a 1,000 kg annual harvest quota for all species combined. Further, all taxa of precious corals were defined as management unit species. Amendment 2 to the FMP (pending as of May 1991) has defined "overfishing" as ". . . overfished with respect to recruitment [at a particular bed] when the total spawning biomass (of all species combined) has been reduced to 20% of its unfished condition."

Although several valuable resources (e.g., the finfish *Etelis coruscans*) co-occur in precious coral habitat, there is no bycatch problem. No predators or prey of precious corals are impacted by the fishery. There are no marine mammal-fishery interactions.

For further information

Grigg, R. W. 1976. Fishery management of precious and stony corals in Hawaii. University of Hawaii Sea-Grant-Tr-77-03:1-48.

Grigg, R. W. 1988. Recruitment limitation of a deep benthic hard-bottom octocoral population in the Hawaiian Islands. Mar. Ecol. Progr. Ser. 45:121-126.

Grigg, R. W. 1989. Precious coral fisheries of the Pacific and Mediterranean. *In:* J. F. Caddy (editor), Marine invertebrate fisheries: their assessment and management, pp. 637-645. John Wiley & Sons, N.Y.

Table 18. Current and potential yields (t/year) for coral.

Bed/coral type	RAY	CPY	LTPY	Status
Makapu'u/pink coral	0	1.00	1.00	unexploited
DO /gold coral	0	0.30	0.30	unexploited
DO /bamboo coral	0	0.25	0.25	unexploited
Conditional beds/all	0	DO[1]	DO[1]	unexploited
Refugia/all	0	N/A	N/A	protected
Exploratory fishing areas[2]/all	0	-----	1.0 per area	unexploited

[1]Ditto--Same as at Makapu'u, on a bed-specific, areal basis.

[2]Three areas are recognized: the exclusive economic zones seaward of Hawaii, American Samoa, and Guam.

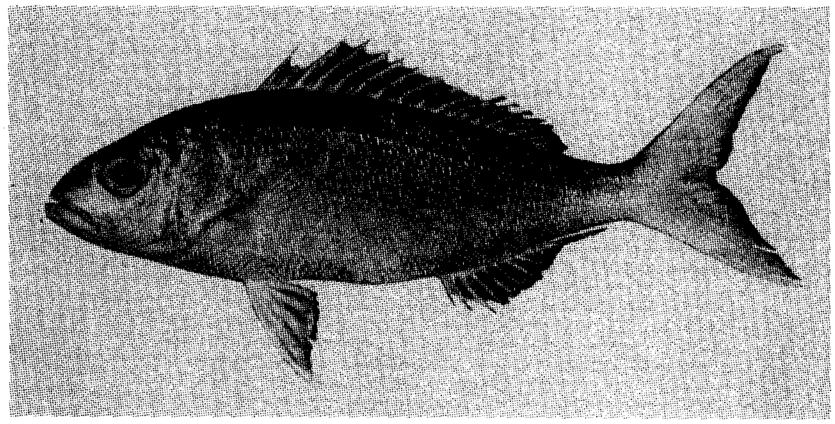
Table 19. Resource summary - precious coral statistics based on data for pink coral at Makapu'u.

Average catch (1980-90)	=	0.05 mt
Long-term potential catch (MSY)	=	1.5 t per 3.5 km^2 per year for 2 years
ABC (1990)	=	0.00 mt
Importance of recreational fishery	=	None
Management	=	Precious coral FMP
Status of exploitation	=	Unexploited
Size at 50% recruitment	=	No size limit (unselective methods); >10-inch colony height (selective method)[1]
Size at 50% maturity	=	>12-cm height (both sexes)
Assessment approach	=	MSY
F (1990)	=	0.00

[1]Applicable to three beds only: the Makapu'u (E-B-1) bed, the Keahole Point, Hawaii (C-B-1) bed, and the Kaena Point, Oahu (C-B-2) bed.

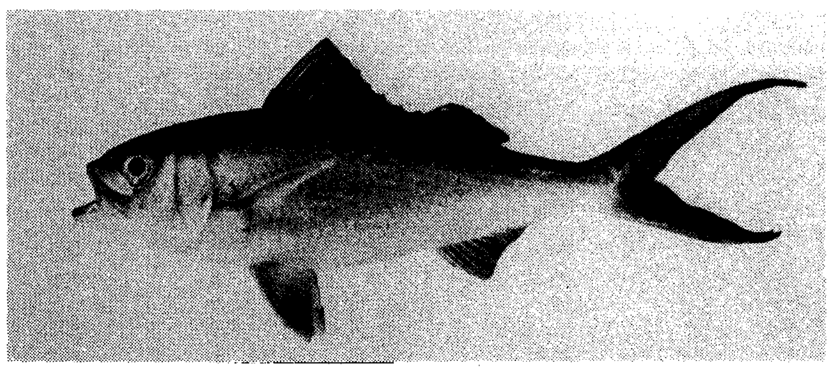
11. WESTERN PACIFIC BOTTOMFISHES

Western Pacific bottomfishes comprise a broad array of species, the most important of which are in the snapper, jack, and grouper families and, in the more tropical areas, the emperor family. The preferred habitat of the bottomfishes is as varied as their taxonomic affinities, but they are most abundant on rock and coral bottoms between depths of 50 and 400 m. Maximum sizes range from about one pound for the smallest of the snappers upwards to over 100 pounds for the largest of the jacks and groupers. All are marketed fresh, usually in the round, and are highly valued.

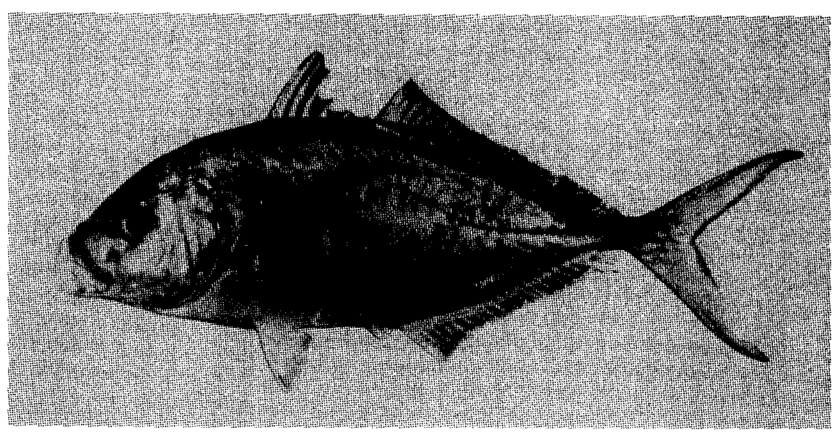


Opakapaka

The fishery for these species is managed under the Bottomfish and Seamount Groundfish Fishery Management Plan (FMP) and geographically encompasses the main Hawaiian Islands (MHI), the Northwestern Hawaiian Islands (NWHI), the territory of Guam, the Commonwealth of the Northern Mariana Islands, and the territory of American Samoa. Throughout this area, bottomfishes are caught primarily with a fishing technique known as "handlining" in which a weighted line with several baited hooks is raised and lowered with a powered or hand-operated reel. Other aspects of the fishery--such as vessel size, trip duration, and the importance of the sport catch--vary among areas.

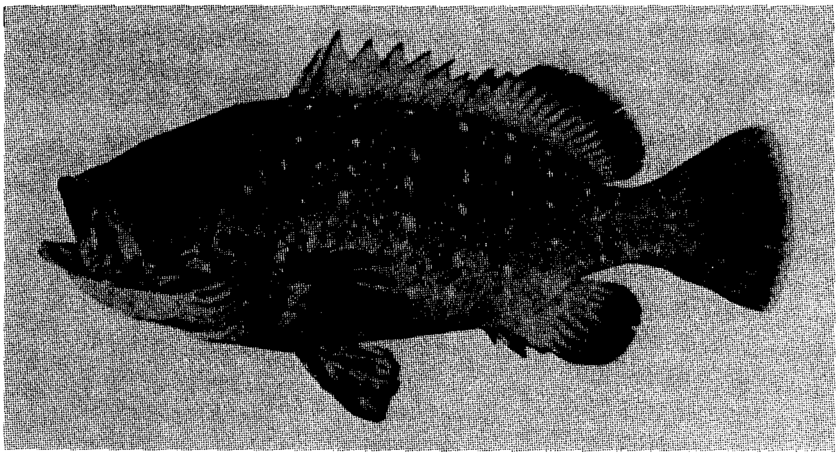


Onaga



Butaguchi

In the MHI, the bottomfish catch consists primarily of opakapaka, *Pristipomoides filamentosus*; onaga, *Etelis coruscans*; and uku, *Aprion virescens*, and represents approxi-



Hapuupuu

Table 20. Reported catch of all bottomfishes and catch per day in the Main Hawaiian Islands (MHI) and in the Northwestern Hawaiian Islands (NWHI).

YEAR	MHI		NWHI	
	LANDINGS (MTONS)	CPUE (LBS/DAY)	LANDINGS (MTONS)	CPUE (LBS/DAY)
1948	298	331	96	746
1949	323	406	123	1174
1950	269	308	152	892
1951	244	398	160	1006
1952	242	489	240	1046
1953	206	697	207	1598
1954	177	437	125	1411
1955	174	458	147	1201
1956	218	492	58	913
1957	199	421	40	772
1958	196	401	27	992
1959	141	336	32	1287
1960	126	527	49	1362
1961	131	492	34	1083
1962	159	473	29	515
1963	191	420	41	853
1964	184	464	47	990
1965	160	470	25	1231
1966	187	438	22	878
1967	164	564	27	1671
1968	272	626	15	556
1969	170	389	18	664
1970	122	319	34	549
1971	152	306	34	396
1972	166	322	19	284
1973	178	260	28	268
1974	167	255	22	307
1975	227	301	27	383
1976	228	273	27	392
1977	252	295	41	450
1978	271	471	66	1122
1979	265	260	54	676
1980	293	297	37	434
1981	314	279	26	333
1982	343	271	28	293
1983	326	168	62	244
1984	348	180	106	288
1985	337	166	135	308
1986	350	196	144	277
1987	343	193	148	562
1988	382	171	134	441
1989	433	188	105	284

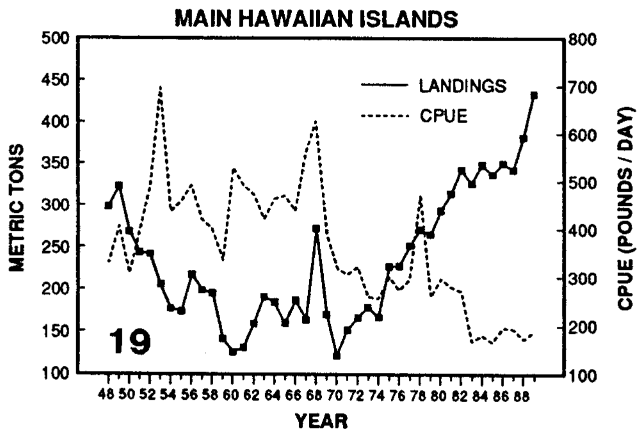
mately 72% of the total managed western Pacific bottomfish catch. In recent years, the MHI catch has continued to increase, and catch-per-unit-effort (CPUE) has continued to decline. Based on changes in CPUE and fish size, since the inception of the fishery in 1947, opakapaka and onaga currently have levels of spawning stock biomass between 20% and 30% of their virgin biomasses. This was considered sufficiently close to the overfishing condition defined in the FMP that restrictive management actions are being examined, especially an increase in the minimum size limit or the imposition of a closed fishing season.

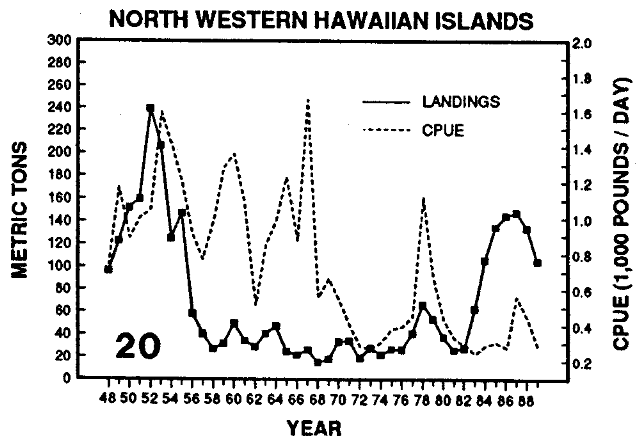
In the NWHI, the bottomfish catch consists primarily of opakapaka; onaga; butaguchi, *Pseudocaranx dentex*; and hapuupuu, *Epinephelus quernus*, and represents approximately 19% of the total. In recent years, the NWHI catch has declined in response to both a decline in CPUE and a decline in effort. Although this suggests some decline in the stocks, the landed size distribution indicates that the stocks are still lightly fished. The NWHI is unique among the five areas in that the fishery is strictly limited entry.

In the remaining three areas, where the bottomfish catch is small, fluctuation in catch appears to be driven by ex-vessel price and opportunities in other fisheries rather than biological productivity of the stocks, and there is no indication of overfishing.

Table 21. Total catch of all bottomfishes and either catch per day or catch per trip in the Territory of Guam, American Samoa and the Commonwealth of the Northern Marianas Islands (CNMI).

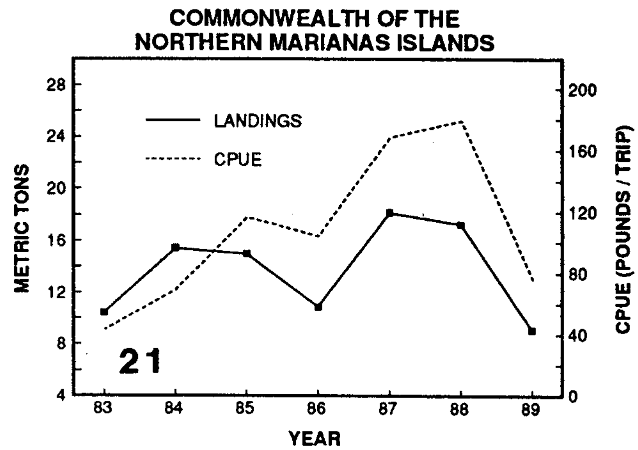
YEAR	GUAM		SAMOA		CNMI	
	LANDINGS (mt)	CPUE (lbs/hr)	LANDINGS (mt)	CPUE (lbs/hr)	LANDINGS (mt)	CPUE (lbs/trip)
1980	10.88	6.5				
1981	24.49	7.6				
1982	23.58	7.6	29.48	8.5		
1983	20.41	5.1	57.15	10.4	10.43	43
1984	22.22	7.7	42.63	13.2	15.42	69
1985	36.74	7.1	46.72	8.2	14.96	116
1986	11.79	5.9	45.35	9.6	10.88	104
1987	14.06	5.6	14.06	12.5	18.14	168
1988	21.77	5.3	29.02	19.7	17.23	179
1989	23.13	5.3	20.41	15.3	9.07	76

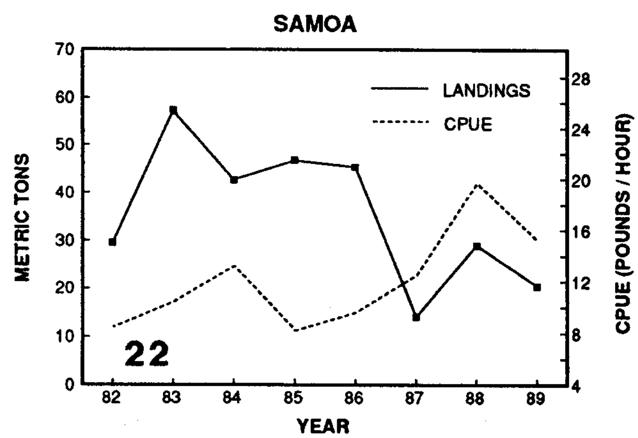




Captions for figures 19-23:

19) Reported catch of all bottomfishes and catch/day in the Main Hawaiian Islands. 20) *Same as previous* in the Northwestern Hawaiian Islands. 21) Total catch of all bottomfishes and catch/trip in the Commonwealth of the Northern Marianas Islands. 22) Total catch of all bottomfishes and catch per hour in the Territory of American Samoa. 23) *Same as previous* in the Territory of Guam.





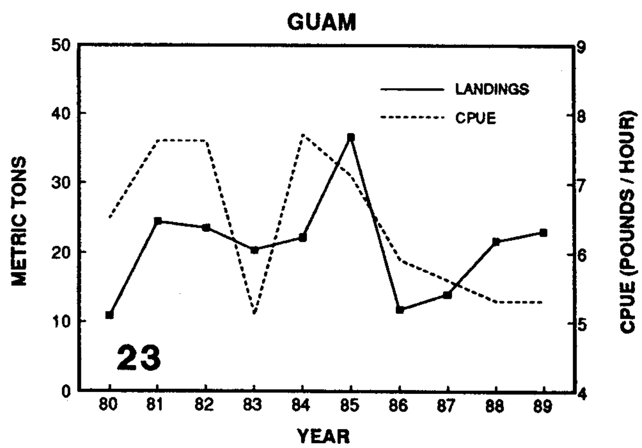


Table 22. Resource summary-onaga *(Etelis coruscans)*.

Average catch (1984-1990)	=	102 mt (MHI) 25 mt (NWHI)
Long-term potential catch (MSY)	=	Unknown (MHI and NWHI)
ABC (1990)	=	Unknown
Importance of recreational fishery	=	Moderate (MHI) None (NWHI)
Management	=	Bottomfish & Seamount Groundfish FMP
Status of exploitation	=	Max. production (MHI) Underexploited (NWHI)
Size at 50% recruitment	=	32 cm (MHI) 57 cm (NWHI)
Size at 50% maturity	=	66 cm
Assessment approach	=	Spawning Potential Ratio*
F (1990)	=	Unknown

*Ratio of existing spawning stock biomass to virgin spawning stock biomass.

Table 23. Resource summary-opakapaka *(Pristipomoides filamentosus)*.

Average catch (1984-1990)	=	114 mt (MHI) 116 mt (NWHI)
Long-term potential catch (MSY)	=	Unknown (MHI and NWHI)
ABC (1990)	=	Unknown
Importance of recreational fishery	=	Moderate (MHI) None (NWHI)
Management	=	Bottomfish & Seamount Groundfish FMP
Status of exploitation	=	Max. production (MHI) Underexploited (NWHI)
Size at 50% recruitment	=	31 cm (MHI) 52 cm (NWHI)
Size at 50% maturity	=	43 cm
Assessment approach	=	Spawning Potential Ratio
F (1990)	=	Unknown

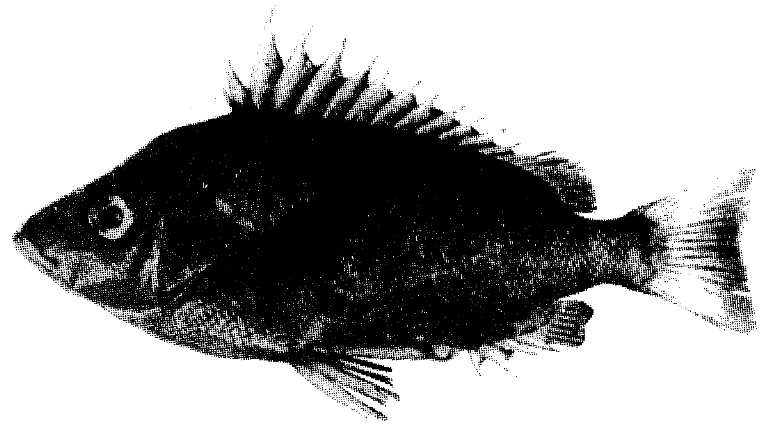
Table 24. Resource summary-uku *(Aprion virescens)*.

Average catch (1984-1990)	=	92 mt (MHI) 8 mt (NWHI)
Long-term potential catch (MSY)	=	Unknown (MHI and NWHI)
ABC (1990)	=	Unknown
Importance of recreational fishery	=	Moderate (MHI) None (NWHI)
Management	=	Bottomfish & Seamount Groundfish FMP
Status of exploitation	=	Max. production (MHI) Underexploited (NWHI)
Size at 50% recruitment	=	53 cm (MHI) 66 cm (NWHI)
Size at 50% maturity	=	45 cm
Assessment approach	=	Spawning Potential Ratio
F (1990)	=	Unknown

Table 25. Resource summary-butaguchi *(Pseudocaranx dentex)*.

Average catch (1984-1990)	=	4 mt (MHI) 57 mt (NWHI)
Long-term potential catch (MSY)	=	Unknown (MHI and NWHI)
ABC (1990)	=	Unknown
Importance of recreational fishery	=	Moderate (MHI) None (NWHI)
Management	=	Bottomfish & Seamount Groundfish FMP
Status of exploitation	=	Max. production (MHI) Underexploited (NWHI)
Size at 50% recruitment	=	36 cm (MHI) 54 cm (NWHI)
Size at 50% maturity	=	Unknown
Assessment approach	=	Spawning Potential Ratio
F (1990)	=	Unknown

12. PELAGIC ARMORHEAD



Pelagic armorhead, *Pseudopentaceros wheeleri*, occur on many of the highest peaks of the Hawaiian Ridge and Emperor seamount chains where they form dense aggregations that have been the target of Japanese and Soviet bottom trawlers since 1968. The combined catches of armorhead from all seamounts peaked in 1972, when catch rates exceeded 60 mt/h, but subsequently declined to low levels. Relative population size, based on Japanese catch per unit effort (CPUE), declined to approximately 0.5% of the 1972 level by the early 1980s.

On the Hancock Seamounts, which encompassed the only part of the fishery within the U.S. exclusive economic zone, regulation of the catch was initiated in 1977 under a preliminary fishery management plan (FMP). Catches continued to decline, however, and fishing ceased in 1984. Two years later, with the final approval of the Bottomfish and Seamount Groundfish FMP, a 6-year moratorium prohibiting trawl fishing on the Hancock seamounts became effective. To continue armorhead stock assessment on the Hancock Seamounts after the fishery ended, the NMFS in 1985 initiated a program of standardized stock assessment cruises which sampled the stock using bottom longlines. Research longline CPUE has varied since 1985 without an increasing trend as was antici-

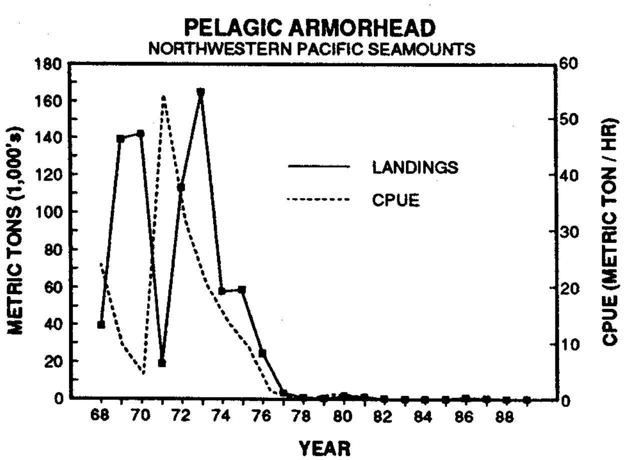


Figure 24. Total catch and Japanese CPUE on all Emperor and Hawaiian Ridge Seamounts.

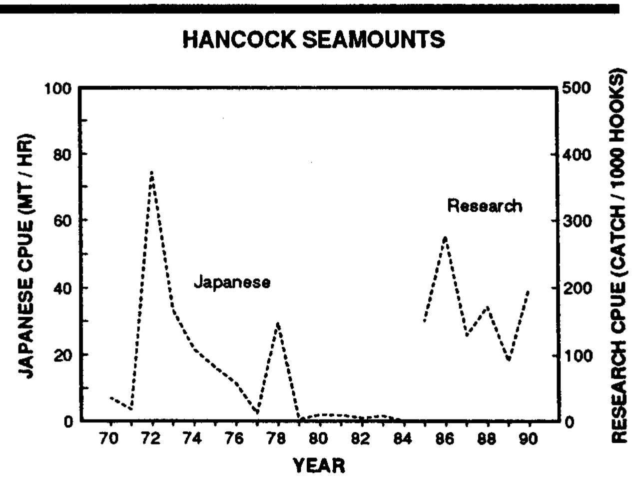


Figure 25. Japanese (left) and research (right) CPUE on Southeastern Hancock seamount.

pated after imposition of the fishing moratorium.

There are two reasons the armorhead population failed to show a measurable response to the fishing moratorium. First, since armorhead cease growth after recruitment to the seamounts, population biomass cannot increase from the growth of individual fish after a reduction in fishing effort. Second, since all of the seamounts probably comprise a single breeding population, closure of the Hancock Seamounts, which comprise approximately 1% of the total armorhead habitat, provides insufficient protection of the breeding population to allow increased recruitment.

Although the United States has never fished armorhead, there is strong Japanese demand for this species and if the stock were to recover, a lucrative domestic fishery could be established on the Hancock Seamounts. In this event, U.S. consumers might finally have the opportunity to savor this delicious and highly esteemed fish. Recovery, however, will require a concerted effort to establish some international agreement to limit fishing.

Table 22. Total Soviet and Japanese catch and Japanese catch per hour of pelagic armorhead an all Emperor and Hawaiian Ridge Seamounts.

Year	Landings (mt)	CPUE (mt/hr)
1968	39,600	0
1969	139,410	23.9
1970	142,410	9.6
1971	19,146	4.53
1972	113,226	54.08
1973	164,755	31.72
1974	57,884	20.47
1975	58,946	13.97
1976	24,829	9.159
1977	3,448	1.403
1978	875	0.376
1979	499	0.294
1980	1,837	0.864
1981	1,211	0.743
1982	524	0.282
1983	52	0.074
1984	174	0.063
1985	89	0.058
1986	902	0.307
1987	454	0.235
1988	186	0.099
1989	140	0.074

Table 23. Total Japanese landings and catch per hour on Hancock Seamounts.

Year	Landings (mt)	CPUE (mt/hr)
1970	320	7.111
1971	81	3.522
1972	3,358	74.622
1973	8,004	33.49
1974	624	21.517
1975	1,321	16.308
1976	1,112	11.347
1977	70	2.414
1978	178	29.67
1979	67	0.72
1980	231	2.044
1981	403	1.824
1982	205	0.95
1983	212	1.537
1984	39	0.203

Table 24. U.S. research catch per unit effort on Southeastern Hancock Seamount.

Year	Research CPUE catch/1000 hooks
1985	150.512
1986	276.801
1987	128.727
1988	172.139
1989	90.49
1990	197.083

Table 25. Resource summary- pelagic armorhead

Average catch (1980-1989)	=	572 mt
Long-term potential catch (MSY)	=	Unknown
ABC (1990)	=	0.00 t
Importance of recreational fishery	=	None
Management	=	Bottomfish & seamount groundfish FMP
Status of exploitation	=	Overexploited
Size at 50% recruitment	=	20.3 cm (females) 20.1 cm (males)
Size at 50% maturity	=	20.3 cm (females) 20.1 cm (males)
Assessment approach	=	Stock Production Ratio
F (1990)	=	Unknown

13. HAWAIIAN MONK SEAL

Breeding populations of the Hawaiian monk seal, *Monachus schauinslandi*, occur almost exclusively at the small uninhabited islands in the northwestern half of the Hawaiian Archipelago. Monk seals are seen infrequently near the main, inhabited islands of Hawaii. Few data exist on the number of monk seals before 1957, when all island populations were counted for the first time. From the late 1950s to the mid-1970s, the number of monk seals declined by approximately 60%. The causes of this decline have been linked primarily to human disturbance of the seals' breeding habitat. In 1976, the Hawaiian monk seal was listed as endangered under the Endangered Species Act.

There is no significant sexual dimorphism in the monk seal in general external features or size; both sexes attain adult lengths of 2.3 m and weights of about 225 kg. The pupping season extends from February to July, with the peak in May. Pups are black at birth and weigh 13-15 kg. During the 5- to 6-week nursing period, the mother attends her pup constantly and does not feed herself. The pup grows to about 75 kg and molts its black fur to a silver-gray color around the time of weaning.

Post-weaning mortality of young seals is due to entanglement in marine debris, attacks by adult male monk seals, predation by tiger sharks, and emaciation. Survival to breeding age at 5-6 years is about 50%. Approximately 60% of all mature females give birth each year, and they may live to 20-25 years of age.

Hawaiian monk seals prey on many reef fishes, as well as octopus and lobster. Foraging distribution and activity are poorly understood. Limited data on diving patterns indicate that for adult males about half of their foraging activity is shallower than 35 m and the rest to as deep as 100-150 m. Resightings of tagged seals indicate a few individuals travel between breeding islands; most monk seals remain at their natal island for life.

The decline in monk seal numbers slowed in the 1970s. In 1980, the National Marine Fisheries Service (NMFS) began the process of designating "critical habitat" for monk seals, appointed a recovery team to develop a recovery plan, and initiated a program at its Honolulu Laboratory to conduct research and recovery activities. Critical habitat was designated in 1986, then extended in 1988 to include all of the breeding beaches in the Northwestern Hawaiian Islands (NWHI) and waters around the islands including Maro Reef, a known foraging location, to a depth of 20 fm. The Hawaiian Monk Seal Recovery Team continues to meet regularly to review research findings and advise NMFS on monk seal research and recovery activities.

Initial priorities in the research program included population assessments and monitoring at the major breeding locations and recovery actions directed at the Kure Atoll population, which was known to have

Table 26. Minimum number of Hawaiian monk seals born at the major breeding locations in the Northwestern Hawaiian Islands, 1981-1990.

Location	BIRTHS PER YEAR									
	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
French Frigate Shoals	—	—	98	106	96	108	121	127	119	92
Laysan Island	27	30	24	31	32	34	34	45	33	17
Lisianski Island	—	28	25	16	15	22	19	23	—	17
Pearl and Hermes Reef	—	—	11	17	19	18	22	21	15	10
Kure Atoll	10	5	4	6	5	1	6	8	11	7
TOTAL	—	—	162	176	167	183	202	224	—	143

Table 27. Mean beach counts of Hawaiian monk seals, other than pups, at the 5 major breeding locations in the Northwestern Hawaiian Islands (1983-1990).

Location	MEAN BEACH COUNTS PER YEAR							
	1983	1984	1985	1986	1987	1988	1989	1990
French Frigate Shoals	181.0	221.0	266.7	283.7	260.6	241.2	267.8	253.1
Laysan Island	81.2	78.5	96.7	126.1	133.1	81.5	78.1	73.7
Lisianski Island	86.0	68.1	79.1	93.8	93.0	—	—	75.0
Pearl and Hermes Reef	26.6	31.2	44.7	45.2	36.2	49.3	52.1	38.5
Kure Atoll	22.4	18.8	22.1	26.1	24.7	25.7	26.6	26.5

been depleted by 80% during the previous two decades.

In 1981, NMFS began collecting weaned female pups at Kure Atoll for temporary captive maintenance to enhance first-year survival. This work, known as the Head Start Project, continued over the last decade and has successfully reversed the decline in numbers. The pups are released at the end of their first summer, and survival has been high. Seals of the 1981 and 1982 cohorts began giving birth in 1987, and the number of births has increased as more graduates of the Head Start Project have been recruited. The breeding potential of the population has also been bolstered by moving rehabilitated young female seals from French Frigate Shoals to Kure Atoll. The Kure Atoll population now contains a high proportion of immature seals, about two-thirds of which are female; survival is high, boding well for future growth.

Research is also being directed at a phenomenon termed "mobbing." Research aims are to determine the cause or causes of mobbing and its population effects and to identify a method of ameliorating the problem. Mobbings are attacks by a group of adult male seals on an adult female or young seal of either sex. These attacks often result in the injury or death of the attacked animal. This behavior occurs primarily at Laysan and Lisianski Islands, where the adult sex ratio is highly skewed toward males.

Beginning in 1983, births at the breeding islands were monitored as an index of population status. Births increased through the mid-1980s, peaking at 224 in 1988. In 1989, births declined, followed by an even greater decline to 143 in 1990, probably the lowest number of births per year during the last decade. Except at Kure Atoll, where special management actions are being taken to help the population recover, the 1989-90 decline in births was evident throughout the NWHI. Total beach counts of seals increased through the early to mid-1980s, but then dropped slightly in the late 1980s.

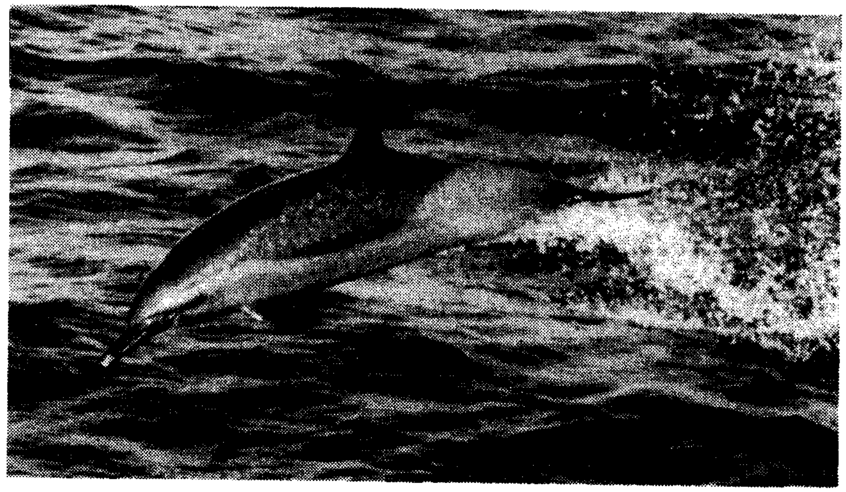
Data from intense population monitoring at Laysan Island in recent years indicate the number of adult females did not change significantly from 1988 to 1990, but the number of adult females giving birth dropped from a normal 61% in 1988 to 28% in 1990. The same phenomenon occurred in the closely monitored Kure Atoll population: 72% of the adult females gave birth in 1988, but only 43% in 1990. Furthermore, tag resighting data from immature seals show a significant increase in mortality between the breeding seasons of 1988 and 1989, and even greater loss of young seals between 1989 and 1990. These data, together with data from some other species in the NWHI, indicate a probable cause of these monk seal declines to be a large-scale environmental phenomenon affecting available food resources, causing significantly higher mortality of young seals and early termination of embryonic development over these two seasons.

Over the last 3 years, a winter longline fishery for swordfish has escalated in the vicinity of FFS. Head wounds on monk seals, suggesting interaction with the longline fleet, were observed in 1990. In February 1991, clear evidence of direct interaction between monk seals and the fishery was observed. Seals with embedded hooks as well as head and neck injuries were noted on FFS beaches, but the full population impact of the interaction could not be assessed. The impact will be indirectly evaluated through beach counts and tag resightings. This fishery is now under an emergency closure within at least 50 nmi of the breeding islands, and the closure will probably be extended indefinitely.

Ten years of effort at Kure Atoll have resulted in changes which appear to be leading that population toward recovery. Identification of the causes of the mobbing problem at Laysan and Lisianski Islands and development of a practicable solution to reduce female mortality are under investigation, but not yet realized. And, as the current situation at FFS clearly demonstrates, large population effects can occur in a short period of time while recovery from these single events may take decades.

14. Spotted dolphins - *Stenella attenuata*

Three stocks of spotted dolphins are currently known to interact with the Eastern Tropical Pacific tuna purse seine fishery: northern offshore, southern offshore, and coastal. A fourth stock, the Hawaiian stock also exists in the ETP, but is not known to interact with the fishery, and therefore, will not be discussed here. Recent information on seasonal movement patterns and patterns of morphological variation suggest that spotted dolphins move outside the previously defined limits of their ranges. Therefore, identification of these stocks should not be made based solely on geographic location alone, but should take into account a combination of morphology and distribution. Definition of stock structure within the spotted dolphin species is currently underway using genetic, taxonomic and distributional data.



The spotted dolphin resembles the common and striped dolphin in overall body shape. Adults range from 1.6 to 2.6 meters long, and weigh up to 100 kg or more, depending on the stock involved. At birth, spotted dolphins are about 80 cm long and are unspotted. In adults, the ventral spots have fused and lightened, giving the animal a uniform gray appearance below. The light spots above persist and are on the average largest and most numerous in the relatively large-bodied coastal stock. The northern offshore and the southern offshore stocks are relatively smaller, more lightly built, have smaller teeth, and, on the average, are less spotted. Stock differentiation between the northern and southern stocks has been made based on external morphology and skull measurements. Spotted dolphins are extremely gregarious and are often found in offshore aggregations of more than 1,000 animals, frequently in mixed herds with spinner dolphins. The coastal form is usually encountered in herds of less than 100 animals.

Northern offshore spotted dolphin

The northern offshore stock is distributed from just below the equator around the Galapagos Islands north to Cabo San Lucas, Mexico to about 145°W. They have been seen as far inshore as 20 km from the coast but are generally distributed farther offshore. Northern offshore animals are on average larger than the southern form, and smaller than the coastal form. Most of what is known about spotted dolphins comes from studies of the offshore race, which is the cetacean most heavily involved in the ETP yellowfin tuna fishery. The life history of the northern offshore stock has been studied intensively. Breeding takes place during prolonged spring and fall seasons. Gestation lasts for 11.5 months, nursing for about 11 months. Since most females "rest" for a few months following lactation, the average calving interval is greater than two years. It is currently thought that dolphin populations under conditions of no incidental take should be increasing at approximately 2-6% per year.

Using research vessel data for the years 1986 though 1990, the northern offshore spotted dolphin population abundance has been estimated. Since 1986, the population size for this stock has varied between 658,300 and 2,205,500 with coefficients of variation (CV) between 29 and 36 percent. Figure 26 graphi-

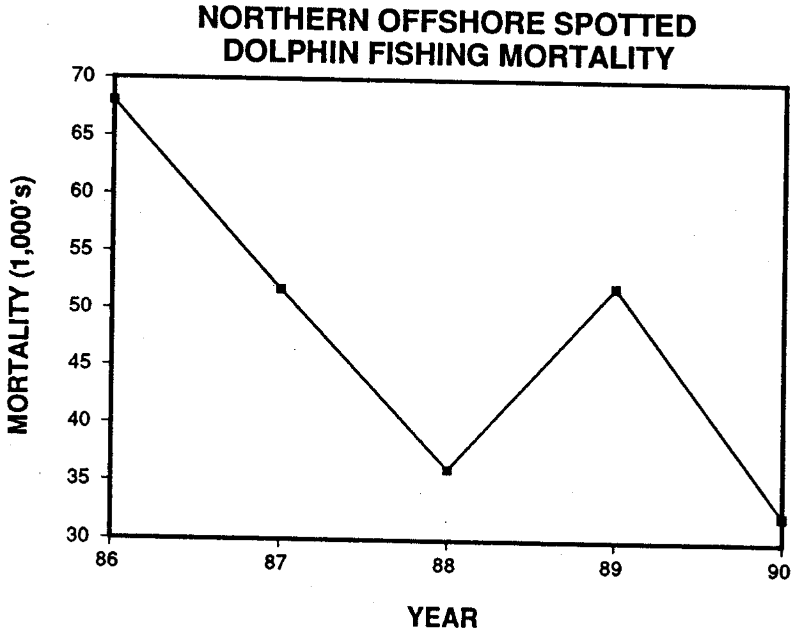


Figure 26.

cally presents total fishing mortality for these same years. These estimates are for the U.S. and foreign fleets combined. The average annual fishery-caused mortality between 1986 and 1990 was around 48,000 animals. Currently, population estimates are plagued with bias and variability, but if it is assumed that the MOPS research vessel estimates are conservative (i.e., negatively biased), then a maximum rate of take can be estimated by dividing the annual estimates of fishing mortality by annual estimates of population abundance. The fishing mortality rate (expressed as a percent) for the northern offshore stock varied between 2.4% and 4.5% over the last five years; however, there is evidence that these rates may be overestimations because of sampling bias.

Over the past 5 years, significant trends in abundance have not been detected based on sighting data collected by observers on U.S. and non-U.S. fishing vessels. Too few data points have been determined from the research vessel surveys (referred to as the Monitoring of Porpoise Stocks (MOPS) cruises) to determine trends in abundance and the analyses of the life history data have not yet been completed. Because the current level of incidental fishing mortality is at a level similar to the expected rate of increase, it is not surprising that significant positive or negative trends in abundance have not been detected in recent years.

Future work on the northern spotted dolphin will be directed at determining its status. Population size estimates based on research vessel surveys, trends analyses based on tuna vessel observer data, and condition index analyses based on life history material will continue. In addition, greater effort to identify the sub-specific population structure of the ETP stocks will be undertaken using recently developed genetic methods of DNA analyses.

Southern offshore spotted dolphin

Analysis of skull morphology and reproductive behavior have justified the separation of the southern offshore stock from the northern offshore stock. It has been found that skulls of spotted dolphins from south of the equator are on average, larger and have smaller temporal fossa than those of animals from north of the equator. The southern stock tends to be, on average, shorter than the northern stock. In addition, calving season in the south is relatively short, March to May.

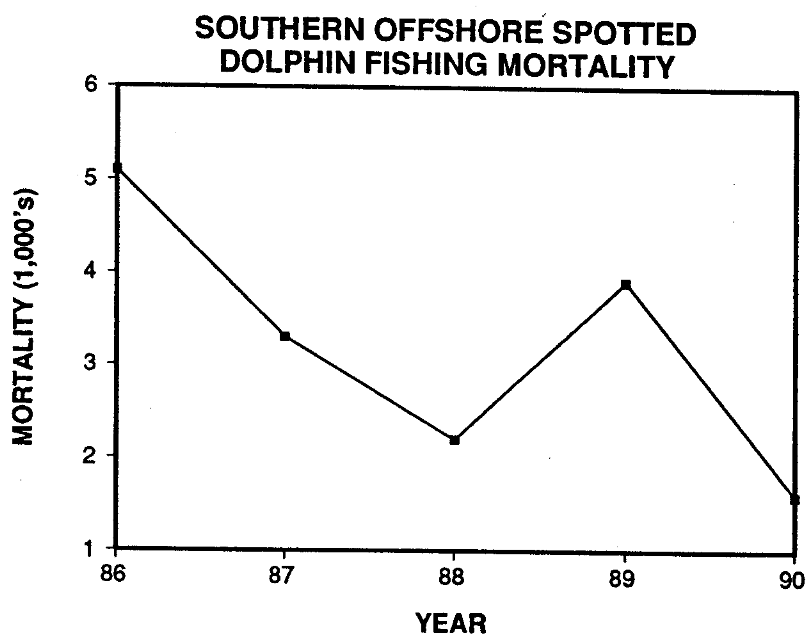


Figure 27.

Using research vessel data for the years 1986 though 1990, the southern offshore spotted dolphin population abundance has been estimated. Since 1986, population estimates for this stock have varied between 85,800 and 475,800, with coefficients of variation (CV) between 48 and 86 percent. The average annual fishing mortality between 1986 and 1990 was around 3,200 animals (Figure 27). Dividing the annual estimates of mortality by conservative (i.e., MOPS) annual estimates of population abundance yields fishing mortality rates (expressed as a percent) for the southern offshore stock between 0.3% and 1.9% over the last five years. As with the northern offshore stock, it is likely that these estimates of mortality are positively biased.

Over the past 5 years no significant trends in abundance have been seen.

Coastal spotted dolphin

The coastal form ranges into the Gulf of California to about 28°N latitude. This coastal stock is normally confined to waters within 50 km of the coast. It occurs continuously along the Mexican, Central American, and South American coasts to well south of the equator. Frequently it is seen around the Tres Marias Islands off Mexico and on the way in and out of Panama, Punta Arenas, and Costa Rica. This stock is larger and more robust than other stocks and exhibits more spotting in all age groups. Light-colored spotting is so extensive that they are sometimes called "silver-backs".

Estimates of fishery-caused mortality for the coastal stock are considered unreliable because of the difficulty in separating the offshore and coastal forms, and because of the low level of effort in nearshore waters. Estimates of abundance are currently unavailable due to the low survey effort within the range of this stock.

Table 28. Resource Summary- Northern Offshore Spotted Dolphin

Average incidental mortality (1986-1990)	=	48,000 for U.S. and international fleets combined
1990 stock size estimate	=	658,300
Fisheries involved	=	Yellowfin tuna purse seine
Management	=	Marine Mammal Protection Act
Status of exploitation	=	Currently there are no significant trends
Age at sexual maturity	=	11 years (females) 15 years (males)
Size at sexual maturity	=	178 cm (females) 186 cm (males)
Assessment approach	=	Trends in relative abundance

Table 29. Resource Summary- Southern Offshore Spotted Dolphin

Average incidental mortality (1986-1990)	=	3,200 for U.S. and international fleets combined
1990 stock size estimate	=	87,700
Fisheries involved	=	Yellowfin tuna purse seine
Management	=	Marine Mammal Protection Act
Status of exploitation	=	No significant trends
Age at sexual maturity	=	10 years (females) Not available for males
Size at sexual maturity	=	175 cm (females) Not available for males
Assessment approach	=	Trends in relative abundance

Table 30. Resource Summary- Coastal Spotted Dolphin

Average incidental mortality (1986-1990)	=	Not available
1990 stock size estimate	=	Not available
Fisheries involved	=	Yellowfin tuna purse seine
Management	=	Marine Mammal Protection Act
Status of exploitation	=	No significant trends
Age at sexual maturity	=	Not available
Size at sexual maturity	=	Not available
Assessment approach	=	Currently being analyzed

15. Spinner dolphins - *Stenella longirostris*

There are four recognized stocks of spinner dolphins in the ETP: northern whitebelly, southern whitebelly, eastern and Costa Rican (now called Central American spinner dolphin). Due to the high degree of overlap in distributions between northern and southern whitebelly spinner dolphin stocks, it has been suggested that northern and southern whitebelly stocks be combined into a single management unit. The stocks affected by the tuna purse seine fishery are the whitebelly and eastern stocks.

Adult spinner dolphins are about 1.5-2.2 meters long, with females on average about 4 cm shorter than males. Size varies among stocks. The Central American spinner which has just received subspecific status, is the longest, adults reaching lengths of 2 meters or more, while the immediately adjacent eastern spinner is the smallest. Central American and eastern spinner dolphins have a peculiar sexual dimorphism in body shape. In adult males, the dorsal fin is erectly triangular; in some cases it is even canted forward appearing to be on "backwards." Also distinct is the postanal hump composed largely of connective tissue. The combination of forward-leaning fin and large ventral hump give large males an appearance unique among the dolphins. The stocks also differ widely from each other in body shape and in color patterns.

Spinners often occur in very large herds, and it is not unusual to find them mixed with spotted dolphins. Both species experience significant fishing mortality in the ETP as a result of tuna purse seine operations. The two stocks most involved are the eastern and whitebelly spinners. The spinner's common name is derived from its habit of leaping clear of the water and spinning on its longitudinal axis rotating as many as seven times in one leap.

Eastern spinner dolphins

Eastern spinner dolphins are, on average, about 3-4 cm smaller than whitebelly spinner dolphins. Patterns of skull size variation between populations were found to be opposite from patterns observed in northern and southern offshore spotted dolphins. That is, animals from the south tended to have larger skulls with a proportionately larger temporal fossa.

Abundance estimates for the eastern spinner stock based on the five MOPS surveys (1986-1990) ranged from 391,200 to 754,200 with CVs between 37 and 42 percent. U.S. fishermen are not allowed to set on pure schools of eastern spinner dolphins, but incidental mortality still exists. The total fishing mortality of eastern spinner dolphins for the years 1986-1990 ranged from 19,500 to 5,400 per year (Figure 28), averaging around 13,860 animals. The estimated level of mortality, expressed as a percent of the population size based on MOPS data, varied between 0.9% and 3.3% for 1986 to 1990. Preliminary analysis has not yet revealed any significant trends in abundance for eastern spinner dolphins over the last 5 years.

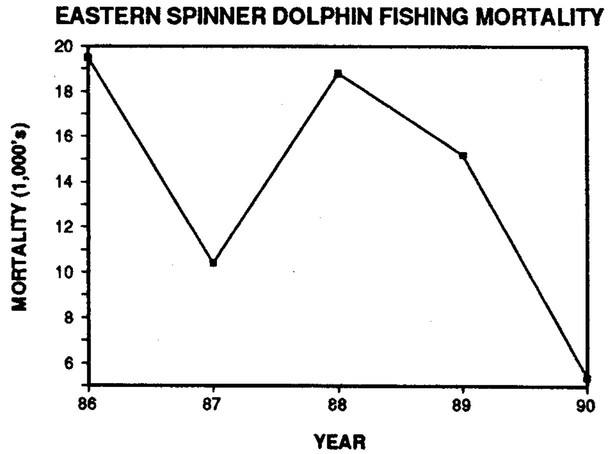


Figure 28.

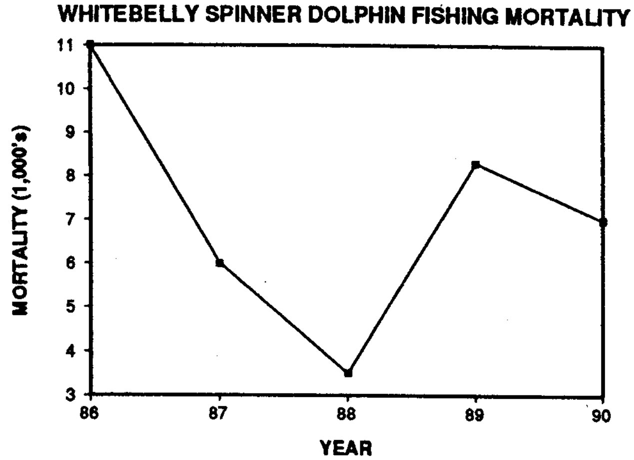


Figure 29.

Whitebelly spinner dolphin

Abundance estimates for the whitebelly spinner stock based on the five MOPS surveys (1986-1990) ranged from 363,300 to 1,398,400 with CVs between 38 and 64 percent. Incidental mortality for the whitebelly stock has been lower than for the eastern stock. Between 1986 and 1990, fishing mortality varied between 3,500 and 11,000 per year (Figure 29). The average mortality for these five years was around 7,160 animals incidentally taken. Percent fishing mortality ranged from 0.4% to 1.1%.

Table 31. Resource Summary- Eastern Spinner Dolphin

Average incidental mortality (1986-1990)	=	13,860
1990 stock size estimate	=	391,200
Fisheries involved	=	Yellowfin tuna purse seine
Management	=	Marine Mammal Protection Act
Status of exploitation	=	No significant trends
Age at sexual maturity	=	Currently being analyzed
Size at sexual maturity	=	165 cm (females) 170 cm (males)
Assessment approach	=	Back calculations and trends in relative abundance

Table 32. Resource Summary- Whitebelly Spinner Dolphin

Average incidental mortality (1986-1990)	=	7,160
1990 stock size estimate	=	363,300
Fisheries involved	=	Yellowfin tuna purse seine
Management	=	Marine Mammal Protection Act
Status of exploitation	=	No significant trends
Age at sexual maturity	=	Currently being analyzed
Size at sexual maturity	=	167 cm (females) 175 cm (males)
Assessment approach	=	Trends in relative abundance

16. Common Dolphins - *Delphinus delphis*

Presently, there are three recognized stocks of common dolphins taken by the U.S. fleet in the ETP (northern tropical, central tropical, and southern tropical). Stock abundance and mortality data are pooled according to observed distribution. Additional information indicates that a Baja neritic stock overlaps the distribution of the northern tropical stock within 100 nautical miles of the coast of Baja California, Mexico, and in the Gulf of California and, therefore, its range and biology should be studied. The extent to which patterns of distribution confound traditional stock identification methods is currently being examined by NMFS.

Fishing mortality levels for the three stocks are highly variable from year to year, but are considerably less in absolute numbers than mortalities of northern offshore spotted dolphins or eastern spinner dolphins. In recent years the central stock has suffered the greatest mortality of the three stocks (see Figure 31).

The maximum body length of the common dolphin is about 2.5 meters, though most individuals are less than 2.3 meters long. Males are slightly larger than females of the same age. Length at birth is about 80 cm. The beak of this dolphin is well-defined, and is often black with a white tip. The most distinctive external feature of this species is the color pattern on the sides. The light ventral field extends up into the cape, yielding a four-part pattern defined by a criss-cross. The back is black, the belly white, the overlap of the cape by the ventral field is tan or yellowish tan, and the area behind the cape is gray. These dolphins are easily identified by their unique pigmentation pattern, but can be confused with striped and Fraser's dolphins.

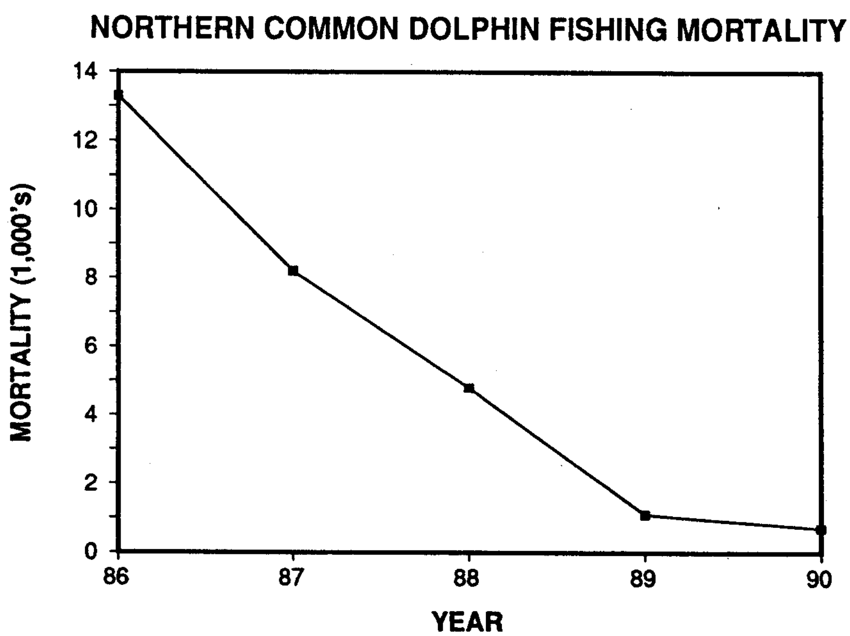


Figure 30.

Northern tropical common dolphin

Northern tropical common dolphins are distributed between latitudes 15°N and 28°N. They are often referred to as short-beaked common dolphins. Because of the overlap in distributions with the Baja neritic stock (long-beaked form), these two stocks have been pooled for abundance and mortality estimation. Abundance estimates based on MOPS data are between 23,500 and 1,272,400 for the northern tropical stock (CVs range from 50 to 77 percent). Annual mortality estimates have been as high as 13,300 in 1986 to a low of 700 in 1990 (Figure 30). The average fishing mortality for these five years was 5,600. The estimated level of fishing mortality, expressed as a percentage of the population size based on MOPS data, varied between 0.2 and 35.9 percent. To date, preliminary analysis has not revealed any significant trends in abundance for the northern tropical common dolphin. Future research will include a more intense survey effort to obtain more accurate abundance estimates for this stock.

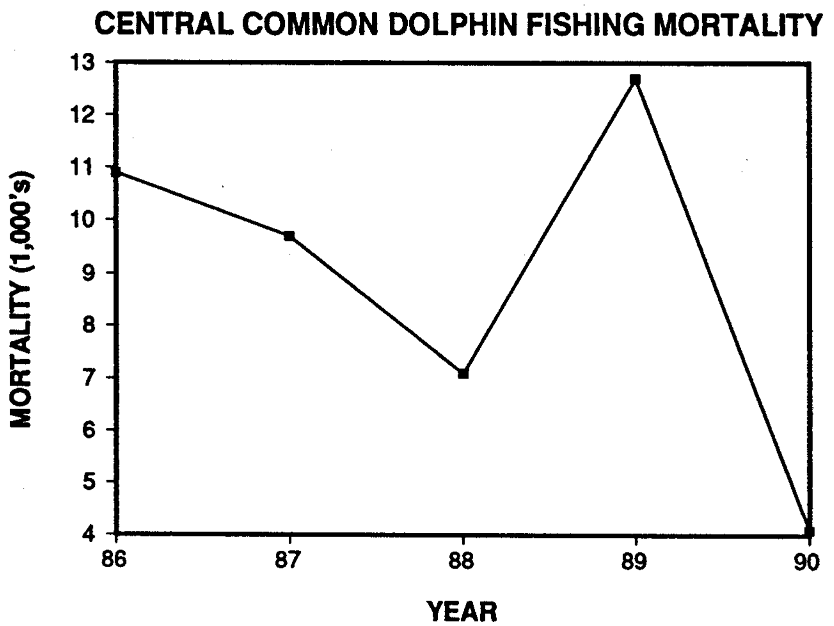


Figure 31.

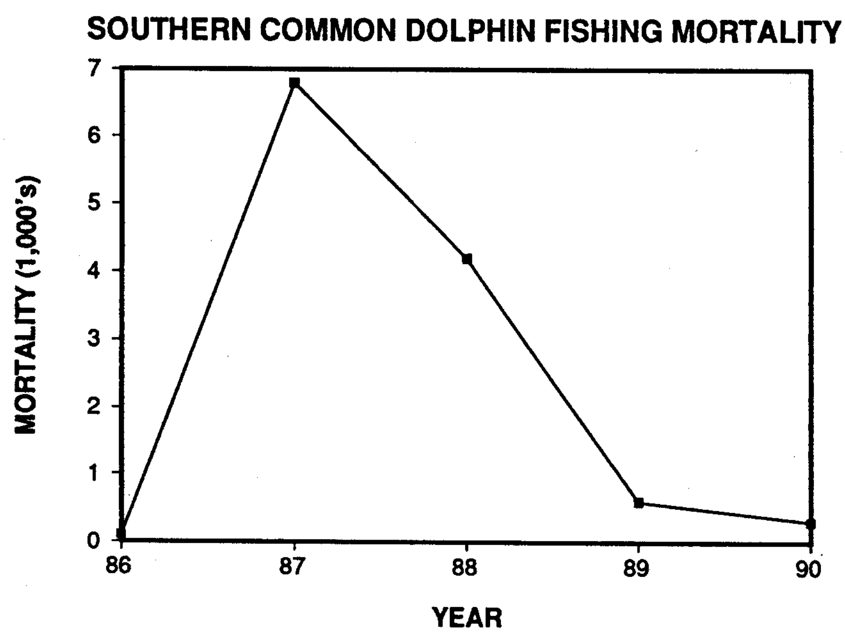


Figure 32.

Central tropical common dolphin

Central tropical common dolphins are distributed between latitudes 3°N and 15°N . They are also known as short-beaked common dolphins, but on average (i.e., mode) are longer than northern tropical common dolphins and have different skull characteristics. The central tropical stock is separated from the northern tropical stock by an 800 nautical mile-wide zone in which sighting effort has been heavy and sightings of common dolphins have been rare.

Abundance estimates for the central tropical dolphin stock were made based on MOPS data for the five survey years (1986-1990) ranging between 261,000 and 1,487,600 (CVs between 50 and 77 percent). In recent years, the central tropical stock has suffered the greatest fishing mortality of the three common stocks. The mortality estimates for the 1986-1990 period range between 4,100 and 12,700 with an average of 8,900 (Figure 31). The estimated level of fishing mortality, expressed as a percentage of the population size based on MOPS data, varied between 0.7 and 2.1 percent.

Southern tropical common dolphin

Southern tropical common dolphins are distributed between latitudes 3°N and 10°S . There is fairly good separation from the central tropical stock. Abundance estimates for the central tropical dolphin stock were made based on MOPS data for the five survey years (1986-1990) and ranged between 152,000 and 3,664,000 (CVs between 50 and 77 percent). The fishing mortality estimates for the 1986-1990 period range between 100 and 6,800 with an average of 2,400 (Figure 32). The estimated level of fishing mortality, expressed as a percentage of the population size based on MOPS data, varied between 0.0 and 0.3 percent.

Table 33. Estimate of total incidental dolphin mortality for U.S. and foreign vessels

YEAR	TOTAL INCIDENTAL MORTALITY
1971	261,928
1972	423,678
1973	264,977
1974	174,682
1975	194,457
1976	128,222
1977	51,353
1978	30,513
1979	21,467
1980	31,970
1981	35,089
1982	29,104
1983	13,493
1984	40,712
1985	58,847
1986	133,174
1987	99,188
1988	78,917
1989	96,979
1990	52,531

Table 34. Resource Summary-Northern Common Dolphin

Average incidental mortality (1986-1990)	=	5,600
1990 stock size estimate	=	177,700
Fisheries involved	=	Yellowfin tuna purse seine
Management	=	Marine Mammal Protection Act
Status of exploitation	=	No significant trends
Age at sexual maturity	=	Currently being analyzed
Size at sexual maturity	=	Currently being analyzed
Assessment approach	=	Trends in relative abundance

Table 35. Resource Summary-Central Common Dolphin

Average incidental mortality (1986-1990)	=	8,900
1990 stock size estimate	=	568,000
Fisheries involved	=	Yellowfin tuna purse seine
Management	=	Marine Mammal Protection Act
Status of exploitation	=	No significant trends
Age at sexual maturity	=	Currently being analyzed
Size at sexual maturity	=	Currently being analyzed
Assessment approach	=	Trends in relative abundance

Table 36. Resource Summary-Southern Common Dolphin

Average incidental mortality (1986-1990)	=	2,400
1990 stock size estimate	=	1,657,500
Fisheries involved	=	Yellowfin tuna purse seine
Management	=	Marine Mammal Protection Act
Status of exploitation	=	No significant trends
Age at sexual maturity	=	Currently being analyzed
Size at sexual maturity	=	Currently being analyzed
Assessment approach	=	Trends in relative abundance

For Further Information:

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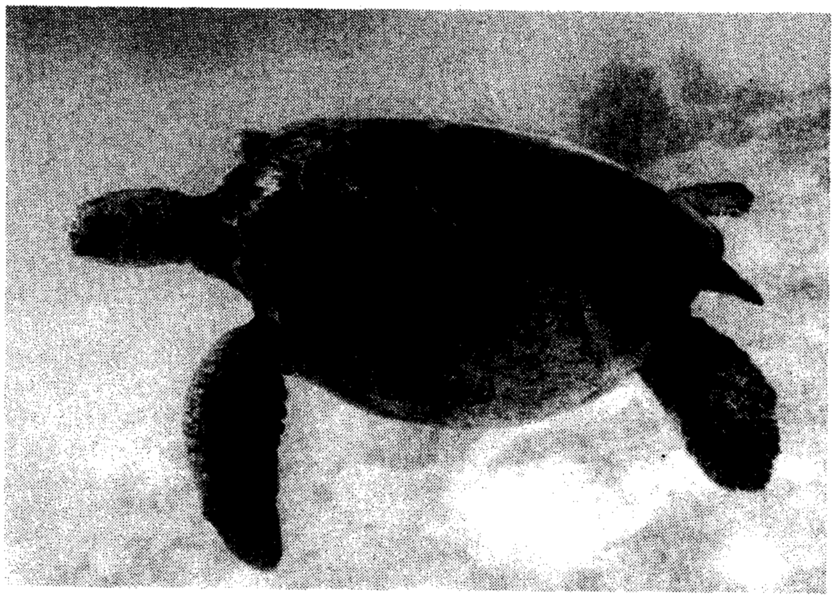
17. HAWAIIAN GREEN TURTLE

As one of seven extant marine turtles, the green turtle, *Chelonia mydas*, is a circumglobal species found in tropical and temperate seas between latitudes 35°N and 35°S. The species consists of separate populations having geographically discrete breeding sites. Considerable circumstantial evidence indicates that these breeding sites are in fact the natal beaches of the adults. The green turtle is listed and protected under the U.S. Endangered Species Act as either "threatened" (in Hawaii and elsewhere worldwide) or "endangered" (in Florida and on the Pacific coast of Mexico). Green turtles worldwide are also listed on Appendix I of the Convention on International Trade in Endangered Species of Fauna and Flora.



Like all green turtles, the Hawaiian green turtle is a long-range migrant breeder that exhibits slow growth and delayed sexual maturity as the result of nutritional limitations of its mainly herbivorous diet. In the Hawaiian Islands, green turtles 35-40 cm in carapace length (CL) establish residency in nearshore benthic habitats where they forage on sea grass, *Halophila hawaiiana*, and selected macroalgae (e.g. *Codium* spp., *Acanthophora spicifera, Amansia glomerata, Pterocladia capillacea, Ulva* spp.). Resting occurs underwater, in association with ledges and other bottom relief that afford shelter and camouflage. Submergence times of 2.5 hours have been recorded by telemetry of undisturbed adults in the wild.

Adult female green turtles (>82 cm CL and >80 kg) in Hawaii undertake reproductive migrations at intervals of 2, 3, 4 years or longer. In contrast, the adult males often migrate to mate on an annual basis. The migratory and colonial breeding site is French Frigate Shoals (FFS; lat. 24°N, long. 166°W), the approximate midpoint of the 2,450 km linear Hawaiian Archipelago. At least 90% of all reproduction by green turtles in Hawaii occurs at FFS, mainly on a 4-hectare islet named East Island. The remainder (<10%) of the nesting takes place at Laysan and Lisianski Islands and Pearl and Hermes Reef, small uninhabited islands to the northwest of FFS. Tagging and resighting data show that green turtles nesting at FFS come from and return to resident foraging pastures throughout the entire length of the Hawaiian Archipelago, as well as from remote Johnston Atoll 800 km to the south of FFS. FFS is a part of the National Wildlife Refuge System administered by the U.S. Fish and Wildlife Service (USFWS). Biologists of the USFWS now maintain a small caretaker and research facility at one of the islets (Tern Island) within FFS.

The nesting season at FFS extends from late April through September, with the major peak of activity taking place during June and July. Copulation, which precedes nesting, occurs in shallow protected waters close to East Island and the five other islets at FFS where the females come ashore to lay their eggs. From one to seven egg clutches are deposited by each turtle at 11- to 18-day intervals within each season. During these inter-nesting intervals, the females actively avoid further mating attempts by males. Both sexes either remain in shallow waters near the nesting beaches or crawl out along the shoreline to bask. Land basking of this nature is rare among sea turtles and is limited to only a few green turtle populations at remote sites in the Pacific Ocean. Thermoregulation, energy conservation by resting ashore instead of underwater, and avoidance of predation by tiger sharks are plausible hypotheses to explain basking behavior by green turtles at FFS.

Hatchling green turtles (5 cm CL) emerge from nests at FFS primarily during the months of July through September. Predation on hatchlings while on land appears to be relatively low (<5%) and confined to ghost crabs, *Ocypode ceratophthalmus* and *O. laevis*. Predation on eggs is virtually nonexistent, as is predation on hatchlings by frigate birds, *Fregata minor*, that nest and roost in large numbers at FFS. Once leaving their natal beaches, the hatchlings swim rapidly away from shore where prevailing westerly currents transport them outside FFS into a pelagic habitat. During an oceanic phase of development that may last for up to 3 years or longer, post-hatchling to juvenile Hawaiian green turtles live at or near the surface. Here they are believed to be omnivorous and feed on macroplankton such as *Physalia, Velella, Janthina*, and various fish eggs. Turtles are affected by ingestion of or entanglement in synthetic, buoyant debris such as plastics which litter the North Pacific in increasing quantities. While in the pelagic habitat, the turtles are seldom encountered and therefore are not accessible to study. However, they appear to congregate in convergence zones and along oceanic fronts where forage density is relatively high. Coincidentally, the convergence zones are also where marine debris collects and where high-seas driftnet fleets operate; therefore, these are areas of relatively high mortality risk for turtles. The pelagic existence ceases for most Hawaiian green turtles at 35-40 cm CL, when recruitment takes place to nearshore benthic habitats where herbivory commences. However, some turtles appear to continue a pelagic existence up to 50 cm CL or more.

Prior to their protection under State and Federal laws, Hawaiian green turtles were exploited for food and commerce. Considerable harvesting of nesting and basking turtles took place at FFS, where turtles were killed and shipped to markets in Honolulu up until at least the 1950s, when enforcement of the refuge boundaries was not feasible. Besides human take, the principal predation on green turtles in benthic habitats of Hawaii is by the tiger shark, *Galeocerdo cuvieri*. Intensive shark fishing and research programs conducted periodically in the Hawaiian Islands until terminated in 1977 showed that green turtles are a common, but by no means exclusive, component of the tiger shark's diet. Although now apparently rare, large groupers, *Epinephelus lanceolatus*, in Hawaii are known to ingest whole juvenile green turtles.

Although mortality due to human take has lessened, other factors threaten the recovery of Hawaiian green turtles. In particular, there is great concern about the effects of green turtle fibropapillomas (tumors). Monitoring of resident inshore habitats suggests an eruption of this disease almost simultaneously in green turtles at certain sites in Hawaii and Florida. At four discrete sites in Kaneohe Bay (Oahu), 121 turtles captured during the past 2 years revealed a prevalence of tumors ranging from 49 to 92%. Off the south shore of Molokai, the incidence has grown from no tumors being present in 1982, to 25% of the local population being affected in 1990.

These fibrous tumors debilitate, disfigure, and are life-threatening to the affected turtles. The tumors are especially damaging when occurring, as they commonly do, on the eyes, in the mouth, and as large (30 cm in diameter) lesions on the axillary and inguinal regions. The cause of this disease remains unknown. Leading causal hypotheses include an unidentified virus or a virus with mediating factors such as pollutants, parasites, immunosuppression, or a genetic predisposition. Other possible etiologies include aberrant wound healing responses, or nonviral tumors that are transmissible by direct contact.

Monitoring tumor incidence is coupled with an ongoing program to tag and recapture immature turtles at several resident foraging areas throughout the Hawaiian Islands. The tagging has also provided data for estimation of growth rates of juvenile and subadult green turtles. These indicate slow growth and that an average of 25 years (range, 10-60 years) may be required to reach sexual maturity. Growth rates are believed to be correlated with the quality and quantity of available forage, and the latitude of the foraging pasture (i.e., faster growth at lower latitudes).

Fibropapillomas may seriously affect survival of immature turtles, and ultimately affect the abundance of breeding adults. The tumors are apt to slow growth, delay maturation, and, in adult females, lengthen the remigration interval. All of these effects will reduce the rate of population recovery and may even lead to population decline.

Monitoring population recovery has focused on the adult females accessible at French Frigate Shoals. At East Island, nesting females have been surveyed, tagged, and otherwise studied during the period of peak nesting activity every year since 1973. Since 1988, comprehensive coverage of all turtles nesting at East Island during the entire season has been possible, because of the cooperative efforts of the USFWS. The annual East Island surveys provide estimates of the nesting population size (Figure 33) and annual hatchling production and a means to monitor trends in the adult female population. The East Island data series suggest some recovery in the nesting population has occurred. Monitoring of the juvenile and subadult segments of the population is also under way, based on data from the inshore tagging program.

Numerical models of Hawaiian green turtle population dynamics are being constructed based on the extensive tag-recovery data base and estimates of life history parameters. The models will be used to evaluate population recovery strategies and critical areas for further research.

A draft recovery plan, as required under the U.S. Endangered Species Act, has been prepared for the Hawaiian green turtle by a recovery team appointed in 1985. This document is currently serving to guide research activities at the SWFSC Honolulu Laboratory. This interim Hawaiian Sea Turtle Recovery Plan will be revised and incorporated in the Pacific-wide Sea Turtle Recovery Plan, which is scheduled for completion in June 1993.

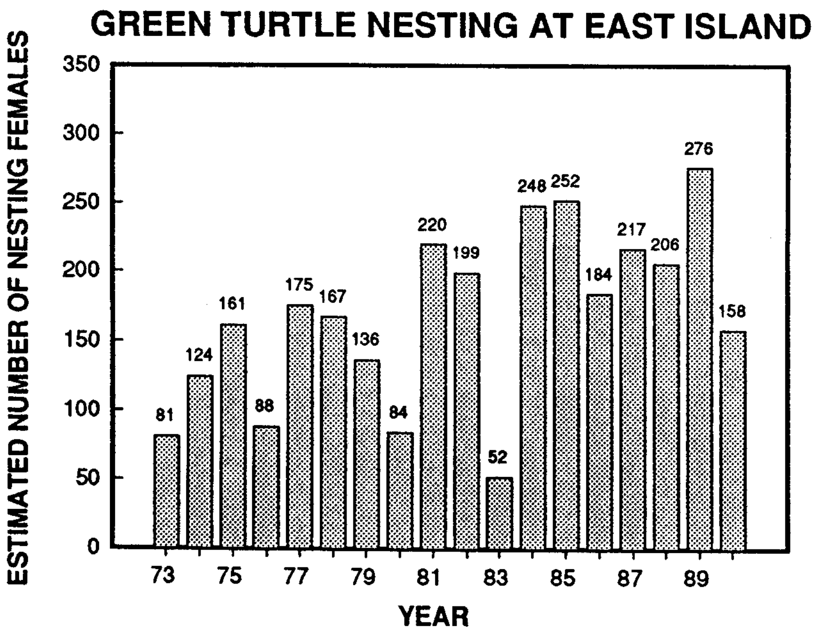


Figure 33.

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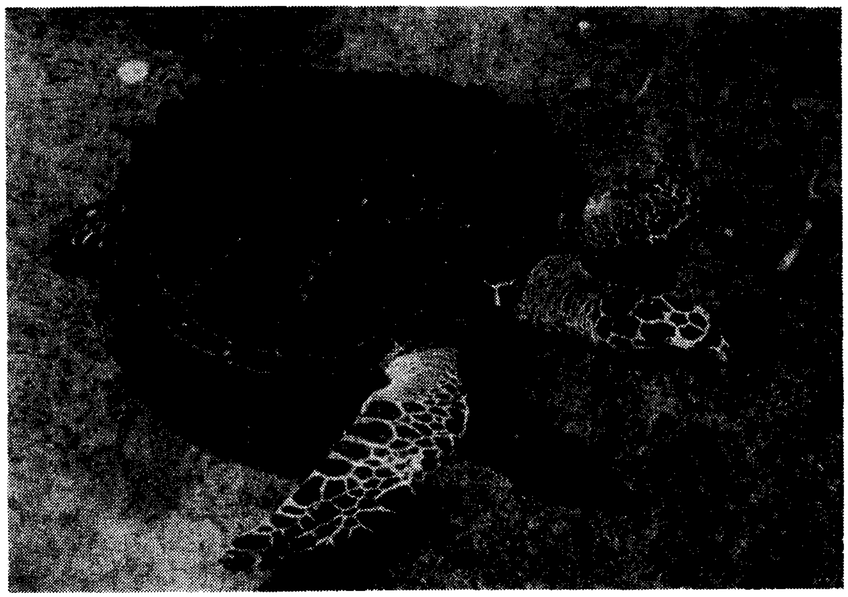
18. HAWAIIAN HAWKSBILL TURTLE

As one of seven extant marine turtles, the hawksbill, *Eretmochelys imbricata*, is a circumtropical species that nests diffusely on tropical beaches and has a highly specific diet of sponges (e.g., Geodiidae, Stellettidae, Chondrosiidae, and Tethyidae). The hawksbill is considered by many authorities to be the most endangered of all marine turtles because of continuing international trade in tortoiseshell or "bekko," the unusually thick and patterned scutes of the turtle's carapace and plastron. According to the U.S. Department of the Interior, Japan imported the shells of at least 234,000 hawksbills in the 1980s and more than 18,000 in 1990. Tortoiseshell is used by craftsmen in Japan to fashion both modern and traditional jewelry, eyeglass frames, and other expensive works of art.



The hawksbill is listed and protected under the U.S. Endangered Species Act as an "endangered" species. In addition, it is included on Appendix I of the Convention on International Trade in Endangered Species of Fauna and Flora. Although Japan is a member of this convention, along with several other nations, it has maintained a reservation in the trade of hawksbill products.

In the Hawaiian Islands, the hawksbill is presently a rare species that is thought to be in immediate danger of local extinction. A serious shortage of information exists on all aspects of its life history and ecology. The hawksbill is only known to occur in the southern portion of the 2,450 km Hawaiian chain, mainly in coastal areas of the islands of Hawaii, Molokai, and Oahu (lat. 19°-22°N). More northerly regions of the Hawaiian chain (lat. 22°-29°N) appear to be unsuitable habitats for hawksbill residency and reproduction.

Hawksbill nesting in Hawaii, which extends from about June through November, is extremely limited in both geographical scope and magnitude. The beaches where nesting is known to take place are exceedingly small and, in some cases, confined to remote locations. These beaches include Halawa at the east end of the island of Molokai; Kailua and Laie on the island of Oahu; and Orr's Beach, Kawa, Punaluu, Kamehame, Apua, and Halape on the island of Hawaii. The latter two sites are within the boundaries of the Hawaii Volcanoes National Park where biologists of the National Park Service, in collaboration with the National Marine Fisheries Service, have recently initiated hawksbill research and management efforts to enhance conservation. Recently covered by lava was another beach (Harry K. Brown Park near Kaimu) on the island of Hawaii where hawksbill nesting occasionally occurred. Not all of the presently known hawksbill nesting beaches have turtles nesting on them each year. The most consistently used sites appear to be Halawa, Kamehame, and Apua. Overall, there may not be more than 15 hawksbills nesting annually on all beaches combined. The preliminary results of studies in the Hawaii Volcanoes National Park indicate low hatch rates of eggs and high hatchling mortality from as yet undetermined causes. At Kamehame, predation on eggs by mongooses, *Herpestes auropunctatus*, is believed to be substantial. This site in particular is in urgent need of a predator control program and other management measures.

Along with the green turtle, *Chelonia mydas*, hawksbills were well known in the early Hawaiian culture. However, unlike the green turtle, the hawksbill was not esteemed for food, probably because of sporadic fatal human poisonings as have been recorded elsewhere even to the present time. This occasional toxicity is thought to be related to spongivory. The early Hawaiians used hawksbill scutes for fishhooks, jewelry, and most importantly as part of the handles of the kahili, a long decorative staff used to signify the presence of chiefs and royalty. There is no information on the historical abundance of hawksbills in Hawaii although it seems likely that the population was larger than at present.

Immature hawksbills are known to share nearshore benthic habitat with the green turtle at several locations. Small numbers of hawksbills have been captured and tagged at Kiholo Bay and Punaluu on the island of Hawaii and at Palaau on the island of Molokai.

A draft recovery plan, as required under the U.S. Endangered Species Act has been prepared for the Hawaiian hawksbill by a recovery team appointed in 1985. This document is currently serving to guide research activities at the SWFSC Honolulu Laboratory. This interim Hawaiian Sea Turtle Recovery Plan will be revised and incorporated in the Pacific-wide Turtle Recovery Plan, which is scheduled for completion in June 1993.

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APPENDICES

Information Digest on Fishery Management

For the convenience of the reader, following is a summary of information on fishery management and assessment approaches for each of the 18 species groups contained in the Species Synopses section of this report.

Large Pelagics

1. South Pacific Albacore

Fishery Management

At present there is no management scheme for South Pacific albacore. However, because of grave concerns over the ecological effects of the drift gillnet fishery and its impacts on the albacore stock and on the existing longline fishery, a convention was adopted in November, 1989, prohibiting use of drift gillnets in the South Pacific regions by signatory nations and discouraging use of the gear by others. Further, in December 1989 a United Nations General Assembly Resolution was issued calling for a moratorium on South Pacific drift gillnet fishing by July 1, 1991, to be in effect until appropriate conservation and management arrangements are established.

Assessment Approaches

Until the recent expansion of the surface fisheries (troll and gillnet), assessment of the South Pacific albacore stock focused on the adult segment of the population which has been historically targeted by the subsurface longline fleet. These early data suggested a steady decline in the adult stock as the longline fishery developed. Because of inadequate data and lack of knowledge of the population dynamics of South Pacific albacore, there are at present no reliable estimates of the potential aggregate yield from all fisheries or the effects of higher surface catches of small fish on the longline catch rates. Research is underway to develop a length-age structured model of stock and fishery dynamics under the scientific guidance of the South Pacific Albacore Research group (SPAR) for assessment of yield potentials and fishery interactions.

2. North Pacific Albacore

Fishery Management

Based on tagging and fishery data, the North Pacific albacore resource is considered to be a separate stock from the South Pacific albacore. Presently, there is no management arrangement for the North Pacific albacore fisheries. In the North Pacific, catch rates and effort in the U.S. troll fishery and in the Japanese pole-and-line fishery have been declining. The creation of an international management forum for the stock is needed, particularly if the fishing nations wish to encourage a recovery of the stock. At this time only an informal scientific forum exists.

Assessment Approaches

The dynamics of the North Pacific albacore stock are not completely understood, although there is some information on instantaneous natural mortality rate, maximum size, and fecundity. In the North Pacific, the presumably overfished condition of the stock, as reflected in declining catch rates and effort, makes collection of data and evaluation of the effects of the drift gillnet fisheries an urgent issue.

3. Blue Marlin

Fishery Management

Blue marlin are caught primarily as a bycatch of longline fisheries targeting tuna. Presently there is no international management for blue marlin nor any international agreement to monitor the fisheries through exchange of data. A federal fishery management plan for the western Pacific does, however, include blue marlin.

Assessment Approaches

A generalized production model fitted to plots of yield versus fishing effort suggests that the resource continues to be overutilized as indicated in previous assessments and that additional increases in effort would result in further declines in catch. Again, as with many other fish stocks, conservation of this resource will require the establishment of international agreements to exchange data and assess stocks.

4. Eastern Tropical Pacific Tunas

Fishery Management

There is no resource-wide fishery management scheme for yellowfin or skipjack tuna. Each coastal state regulates fishing within its EEZ. Until 1980, the Inter-American Tropical Tuna Commission (IATTC) regulated the fishery with a quota management system. Since that time, the fishing countries have not adopted the IATTC recommendations and fishing continues unregulated.

Assessment Approach

The assessment approach for yellowfin is based on examining trends in catch per unit of effort (CPUE). Recent detailed assessments for yellowfin indicate that the long term potential yield in the ETP is about 250,000 mt. This species is apparently fully utilized.

The assessment approach for skipjack in the ETP is based on CPUE and tagging data. The consensus is that the skipjack resource is underexploited, although its long-term potential yield is not known.

5. Western Tropical Pacific Tunas

Fishery Management

There is no overall resource management program in the central and western Pacific for yellowfin or skipjack. The Forum Fisheries Agency (FFA), the Pacific Island organization of tuna fishing nations, has instituted licensing of fishing effort of distant-water fishing fleets. The U.S. fleet is currently limited to 50 purse seiners under the terms of the South Pacific Regional Tuna Treaty.

Assessment Approach

The assessment approach for yellowfin is based on CPUE, and on tagging results for skipjack. Incomplete analyses done to date suggest that the fishery for yellowfin tuna may be nearing full production. Current consensus is that the Pacific skipjack resource is underexploited, although the long-term potential yield is unknown.

The primary issue facing tropical tuna assessment and management in this area is the lack of consensus on a plan for gathering and reporting statistics and on structuring a fishery management/resource conservation organization that includes all stakeholders.

6. Striped Marlin

Fishery Management

Most striped marlin are caught by longline fisheries targeting tuna. No international management arrangement exists for striped marlin, nor is there any international agreement for exchange of data to monitor the fisheries. In the United States, state and federal agencies exercise a few management options, as for example, the prohibition on sale of striped marlin in California. The Western Pacific Regional Management Council (WPRFMC) has a preliminary fishery management plan in place. Most recently, the Council has obtained an emergency moratorium, freezing the number of vessels in the Hawaii domestic longline fishery.

Assessment Approaches

Under the assumption of a single Pacific-wide stock and based on data through 1980, it is probable that the stock could be further exploited without damage to the resource. However, fisheries statistics are presently inadequate to define the true status of the population. Prevention of overexploitation will require the establishment of international agreements to manage the fisheries.

7. Swordfish

Fishery Management

No international management mechanisms exist for swordfish in the Pacific. Current regional management schemes by California and the federal government in the central and western Pacific are probably sufficient to adequately regulate local sport and commercial fisheries; however, these management schemes are not capable of managing the overall resource.

Assessment approaches

The most recent stock assessment in 1989 using data through 1980 indicated that the resource on a Pacific-wide basis may be somewhat underutilized. However, at best, this assessment can be considered provisional because of the unavailability of data to standardize fishing effort statistics. Comparison of Pacific catches with the harvests obtained in the Atlantic suggest that the Pacific stock is substantially underutilized. With the initiation of a moratorium on the entry of new longline vessels into Hawaii's fishery and the curtailment of growth in the California fishery, the status of the resource within the U.S. Pacific Exclusive Economic Zone is not likely to change substantially in the near future.

8. Other Large Pelagics

Included here are a number of bony and cartilaginous pelagic fishes--mahimahi, wahoo, shortbill spearfish, sailfish, and black marlin, and requiem, thresher, and mackerel sharks.

Assessment approaches

Little is known about the stock composition or population dynamics of any of these species. Because of the low fecundity of the sharks, those resources that have been examined show little resiliency to harvest. Because of its high fecundity, early maturation, and multiple batch spawning, mahimahi is probably reasonably resilient to harvest, although considerable fluctuation in harvest level is likely because of the small number of year classes in most fisheries.

Insular Species

9. Hawaiian Lobsters

Fishery Management

The fishery is managed under a fishery management plan (FMP) effective in 1983. The FMP has established minimum sizes for slipper and spiny lobsters and prohibits the harvest of egg-bearing females. After researchers at the Honolulu Laboratory found that escape vents would reduce sublegal catches and mortality due to handling and release, the FMP was amended to require that traps have such vents. Mandatory logbooks now provide daily legal catch and trapping effort. An amendment to the FMP to make it a limited entry fishery is under review.

Assessment Approaches

Commercial catch and effort data are available from the logbooks. Commercial landings and catch per unit effort (CPUE) show the trend typical of a developing fishery, with a period of rapid increase in landings and then decline in CPUE (1983-1985) as the stock is fished down, followed by a period of more stable landings and CPUE (1987-1990). In 1990, effort was 20% above the effort level estimated to achieve maximum sustainable yield (one million lobsters or 625 tons). The relatively low catch in 1990 is believed to be the result of poor recruitment to the fishery. The stock is thus judged to be fully exploited.

10. Precious Corals

Fishery Management

Precious coral resources within the U.S. Exclusive Economic Zone (EEZ) are currently managed by the Western Pacific Regional Fishery Management Council's Precious Coral Fishery Management Plan (FMP), established in September 1983. Fishing is allowed by regular permit or "experimental fishing permit" (EFP) only, although at the present time these corals are not exploited within the U.S. Pacific EEZ. With one exception in 1988, legal domestic harvesting of precious coral within the Exclusive Economic Zone has been nonexistent for the past 12 years. Several amendments to the FMP which regulates precious coral fisheries within the EEZ seaward of the main Hawaiian Islands and Northwestern Hawaiian Islands, Guam, American Samoa, and the U.S. Pacific island possessions of Johnston Atoll, Kingman Reef, and Palmyra, Wake, Jarvis, Howland, and Baker Islands have been developed in recent years.

Assessment approaches

Management guidelines, in the form of site-specific quotas for potential harvest areas, are based solely on estimates of maximum sustainable yield (MSY) calculated for pink, gold, and bamboo corals at the once "established" Makapu'u bed off Oahu, Hawaii, which was exploited between 1974-1979. Quotas for other 'conditional' beds that have fishery potential are extrapolations based on the area of these beds relative to the size of the Makapu'u bed. As a practical matter, the prohibitive costs of fishing difficult-to-harvest deepwater coral resources has effectively stifled exploitation in Hawaiian waters and the surrounding U.S. Exclusive Economic Zone (EEZ).

11. Western Pacific Bottomfishes

Fishery Management

Included here is a broad array of species, the most important being the snapper, jack, and grouper families, and in the more tropical areas, the emperor family. The fishery for these species is managed under the Bottomfish and Seamount Groundfish Fishery Management Plan (FMP), and encompasses the main Hawaiian Islands, the Northwestern Hawaiian Islands (NWHI), the territory of Guam, the Commonwealth of the Northern Mariana Islands, and American Samoa.

Assessment Approaches

In the main Hawaiian Islands, the bottomfish catch has continued to increase and catch per unit effort (CPUE) has continued to decline. In the NWHI, the catch has declined in response to both a decline in CPUE and a decline in effort. The fishery in the NWHI is unique among the five areas in that the fishery is strictly limited entry. In the remaining three areas, where the bottomfish fishery is small, fluctuations in catch and CPUE appear to be driven by economics rather than biological productivity of the stocks. There is presently no indication of overfishing of Western Pacific bottomfishes.

12. Pelagic Armorhead

Fishery Management

Although the U.S. has never fished armorhead, there is a strong Japanese demand for this species and it has been heavily fished by Soviet and Japanese trawlers since 1968. On the Hancock Seamounts, which encompassed the only part of the fishery within the U.S. Exclusive Economic Zone, regulation of the catch was initiated in 1977 under a preliminary fishery management plan. Catches continued to decline, however, and fishing ceased in 1984. Two years later the Bottomfish and Seamount Groundfish Fishery Management Plan was approved. In 1985, the NMFS began a program of standardized stock assessment cruises using bottom longlines; the longline CPUE data show that the armorhead population failed to show a measurable response to the fishing moratorium.

Assessment Approaches

The unusual physiology of the armorhead which has a two-year juvenile pelagic fat phase followed by a 3-4 year adult demersal thin phase prevents an increase in biomass from individual growth after a reduction in fishing effort. It also appears that all of the seamounts probably comprise a single breeding population. Closure of the Hancock Seamounts (while the fishery continued elsewhere) provided insufficient protection of the breeding population to allow increased recruitment. Recovery of the pelagic armorhead will require a concerted effort to establish some international agreement to limit fishing.

Marine Mammals

13. Hawaiian Monk Seal

The Hawaiian Monk Seal Recovery Team was appointed in 1980 to review research findings and advise NMFS on monk seal research and recovery activities. Ten years of effort at Kure Atoll have resulted in changes which appear to be leading that population toward recovery. Identification of causes of the "mobbing" problem at Laysan and Lisianski Islands and development of a practicable solution to reduce female mortality are under investigation.

14. Spotted Dolphin

Three stocks of spotted dolphins are currently known to interact with the tuna purse seine fishery: northern offshore, southern offshore, and coastal. A fourth stock, the Hawaiian stock, also exists in the eastern tropical Pacific but it not known to interact with the fishery.

At this time, there are no significant trends in abundance for the northern spotted dolphin. Population size estimates based on research vessel surveys, trends analyses based on tuna vessel observer data, and condition index analyses based on life history material will continue.

No significant trends in abundance have been seen for the southern offshore spotted dolphin. The time series of population estimates is too short to provide adequate statistics and the life history data have not been fully analyzed.

Fishing mortality estimates for the coastal spotted dolphin are considered unreliable because of the difficulty in separating the offshore and coastal forms, and the low level of effort in nearshore waters. Estimates of abundance are currently unavailable due to the low survey effort within the boundaries of this stock.

15. Spinner Dolphin

The stocks of spinner dolphin affected by the tuna purse seine fishery are the whitebelly and eastern stocks. The number of animals killed in the fishery for the years 1986-1990 ranged from 19,500 to 5,400 per year. Preliminary analysis indicates no significant trends in abundance for eastern spinners.

16. Common Dolphin

Three stocks of dolphins taken by the U.S. fleet in the eastern tropical Pacific are recognized--northern tropical, central tropical, and southern tropical. Mortality due to fishing for the three stocks is highly variable from year to year, but considerably less in absolute numbers than for northern offshore spotted dolphins or eastern spinner dolphins. In recent years, the central stock has suffered the greatest fishing mortality of the three stocks.

Preliminary analysis indicates no significant trends in abundance for the northern tropical common dolphin. Future research will include a more intense survey effort to obtain better abundance estimates for this stock.

Sea Turtles

17. Hawaiian Green Turtle

The Hawaiian green turtle is listed and protected under the U.S. Endangered Species Act as either "threatened" (in Hawaii, and elsewhere worldwide) or "endangered" (in Florida and on the Pacific coast of Mexico). Green turtles worldwide are also listed on Appendix I of the Convention on International Trade in Endangered Species. A draft recovery plan, as required under the U.S. Endangered Species Act, has been prepared for the Hawaiian green turtle.

18. Hawaiian Hawksbill Turtle

The hawksbill, listed and protected under the U.S. Endangered Species Act as an "endangered" species, is considered by many authorities to be the most endangered of all marine turtles. In the Hawaiian Islands, the hawksbill is thought to be in immediate danger of local extinction. A draft recovery plan, as required under the U.S. Endangered Species Act, has been prepared for this turtle.

DEFINITION OF TECHNICAL TERMS

A brief explanation of certain assessment terms used in this document, organized alphabetically, follows. Cross-referenced terms are in bold type.

Allowable Biological Catch: Commonly known as ABC, this is defined in the *Federal Register* of July 24, 1989 as a preliminary description of the acceptable harvest (or range of harvests) for a given stock or stock complex. Its derivation focuses on the status of the stock, environmental conditions, other ecological factors, and prevailing technical characteristics of the fishery. If a threshold has been specified for the stock, ABC must equal zero when the stock is at or below that threshold. ABC may be expressed in numeric or non-numeric terms.

Bycatch: Sometimes called "incidental catch", it is the catch of a particular kind or size of fish by gear fishing primarily for other species or sizes.

Catch per unit effort: Abbreviated as CPUE, it is usually calculated by dividing the catch for a given place and time by the corresponding **fishing effort.**

Dynamic Pool Model: A type of model for fish populations that explicitly considers losses due to natural mortality and fishing as well as gains due to growth and recruitment.

Exploitation Rate: The fraction, by number, of a stock caught in a given time period, usually a year.

F: Mortality caused directly by fishing. In dynamic pool models it is assumed to be like natural mortality, but to be independent of density. In the strict sense, it is the instantaneous coefficient of fish mortality caused by fishing. The **exploitation rate** is the actual proportion of the stock caught in a year.

Fishing: According to the Magnuson Act, fishing means the catching, taking, or harvesting of fish, or attempted catching, taking or harvesting of fish, plus any operations at sea in support of or in preparation for these activities.

Fishing Effort: A measure of the activity expended toward catching fish from a stock, measured in appropriate units such as boat-months or angler-hours.

Fishing Strategy: Manipulating harvest so that fishing mortality (F) is at a defined intended level, i.e., $F_{35\%}$.

Fishery: The Magnuson Act defines a "fishery" as one or more stocks of fish which can be treated as a unit for purposes of conservation and management and which are identified on the basis of geographical, scientific, technical, recreational, and economic characteristics; and any fishing for such stocks.

Generalized Surplus Production Model (GPM): A mathematical model that computes fishery **yield** as a function of **fishing effort** to estimate **maximum sustainable yield** and optimum fishing effort.

Growth overfishing often refers to the practice of taking too many fish from a cohort (year class) before the cohort has attained its maximum potential biomass. It can also mean harvesting at a fishing mortality rate in excess of that which maximizes the expected yield from a cohort given a particular age or size at recruitment (Federal Register, Vol. 54 (140), p. 30842, 1989).

Long-term Potential Yield (LTPY): The maximum yield or surplus production that a stock or management unit of a renewable resource can sustain, at equilibrium, at a given level of fishing effort. It differs from **Long-term Potential Catch (LTPC)** in that LTPC refers to the mass of the resource harvested, which may or may not equal LTPY during a specific time period.

M: Mortality caused by natural causes. More specifically, the instantaneous coefficient of mortality by (natural) causes other than fishing.

Maximum Sustainable Yield or **MSY:** The largest average annual catch or yield that can be taken over a significant period of time from each stock under prevailing ecological and environmental conditions; can be presented as a range of values. MSY may only be a starting point in providing a biological description of allowable fishery removals. It may have to be adjusted because of environmental factors, stock peculiarities, or other biological variables prior to the determination of optimum yield. An example of such an adjustment is determination of Allowable Biological Catch (ABC).

Optimum Yield: The amount of fish which will provide the greatest overall benefit to the nation, with particular reference to food production and recreational opportunities; and which is prescribed as such on the basis of the maximum sustainable yield from each fishery, as modified by any relevant economic, social, or ecological factors. Examples of ecological factors include vulnerability of other fishes in a mixed-species fishery, predator-prey or competitive interactions, or the dependence of marine mammals or birds on a fish stock.

Overfished: A level or rate of fishing mortality that jeopardizes the long-term capacity of a stock or stock complex to produce **maximum sustainable yield** on a continuing basis. The definition of "overfishing" in Fishery Management Plans is or may be much more specific than the above classical definition.

Pelagic Management Unit Species or PMUS: Those species covered by the Fishery Management Plan for the Pelagic Fisheries of the Western Pacific Region, i.e., Indo-Pacific blue marlin, striped marlin, black marlin, shortbill spearfish, swordfish, mahimahi, pompano, dolphinfish, wahoo, and pelagic requiem, thresher, mackerel, and hammerhead shark species.

Recent Average Yield: RAY is the average of landings over the past 3 to 5 years. It may be greater or less than the **long-term potential yield** due to factors such as overfishing, low stock biomass, bad market conditions, or underutilization.

Recruitment overfishing refers to a stock that has been reduced excessively by fishing to the extent that the size of the incoming year classes have also been reduced.

Spawning Potential Ratio: The ratio of existing spawning stock biomass to virgin spawning stock biomass.

Surplus Production Model: A simple mathematical model for fish populations that computes fishery yield as a function of fishing effort to estimate maximum sustainable yield and optimum fishing effort. The **Generalized Surplus Production Model** is one type of production model

Under, Fully, and Overutilized: A stock condition relative to the estimates of **maximum sustainable yield.** For example, an underutilized stock would have larger abundance exceeding that which produces **MSY**.

Y or Yield: The total quantity of fish in the catch. This can be expressed as numbers or weight but it always involves a unit of time, usually a year. In a general sense this refers to the harvest of marine organisms. In some contexts (e.g. **LTPY**), yield includes total surplus production which may not necessarily be harvested.

Year Class: All individuals born or hatched in a single year.

Common and Scientific Name List

Common Name .... **Scientific Name**

Large Pelagics

Albacore .... *Thunnus alalunga*
Blue marlin .... *Makaira mazara*
Yellowfin tuna .... *Thunnus albacares*
Skipjack tuna .... *Euthynnus lineatus*
Striped marlin .... *Tetrapturus audax*
Swordfish .... *Xiphias gladius*

Other Large Pelagics

Dolphinfish or mahimahi .... *Coryphaena hippurus* and *C. equiselis*
Wahoo .... *Acanthocybium solandri*
Shortbill spearfish .... *Tetrapturus angustirostris*
Sailfish .... *Istiophorus platypterus*
Black marlin .... *Makaira indica*
Pelagic requiem sharks - Carcharhinidae
- Silky shark .... *Carcharhinus falciformis*
- Oceanic whitetip .... *Carcharhinus longimanus*
- Dusky shark .... *Carcharhinus obscurus*
- Blue shark .... *Prionace glauca*

Thresher sharks - Alopiidae
- Pelagic thresher .... *Alopias pelagicus*
- Bigeye thresher .... *Alopias superciliosus*
- Thresher shark .... *Alopias vulpinus*

Mackerel sharks - Lamnidae
- Shortfin mako .... *Isurus oxyrinchus*
- Longfin mako .... *Isurus paucus*

Insular Species

Hawaiian lobsters
- Spiny lobster .... *Panulirus marginatus*
- Slipper lobster .... *Scyllarides squammosus*

Precious corals

Pink coral	*Corallium secundum*
Pink coral	*Corallium regale*
Pink coral	*Corallium laauense*
Pink coral	*Corallium* spp.
Gold coral	*Gerardia* spp.
Gold coral	*Callogorgia gilberti*
Gold coral	*Narella* spp.
Gold coral	*Calyptrophora* spp.
Bamboo coral	*Lepidisis olapa*
Bamboo coral	*Acanella* spp.
Black coral	*Antipathes dichotoma*
Black coral	*Antipathes grandis*
Black coral	*Antipathes ulex*

Western Pacific bottomfish

Opakapaka	*Pristipomoides filamentosus*
Onaga	*Etelis coruscans*
Uku	*Aprion virescens*
Butaguchi	*Pseudocaranx dentex*
Hapuupuu	*Epinephelus quernus*
Pelagic Armorhead	*Pseudopentaceros wheeleri*

Marine Mammals

Hawaiian monk seal	*Monachus schauinslandi*
Spotted dolphin	*Stenella attenuata*
Northern offshore	
Southern offshore	
Coastal dolphin	
Spinner dolphin	*Stenella longirostris*
Eastern spinner	
Whitebelly spinner	
Common dolphin	*Delphinus delphis*
Northern tropical common	
Central tropical common	
Southern tropical common	

Sea Turtles

Hawaiian green turtle	*Chelonia mydas*
Hawksbill turtle	*Eretmochelys imbricata*

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